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CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Project type: Network of Excellence (NoE)

Thematic Priority: FP7 Cooperation, Theme 10: Security

Start date of project: March 1, 2013 Duration: 48 months

D9.81 - Courses inside the Homeland Security Master

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Università Campus Bio-Medico di Roma (UCBM)

Project co-funded by the European Commission within the Seventh Framework Programme (2007–2013)		
Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Author(s)	Roberto Setola (UCBM) Claudio Romani (UCBM) Maria Carla De Maggio (UCBM) Maria Elisa Capitello (UCBM)
Contributor(s)	

Security Assessment	H. Duijnhoven (TNO)
Approval Date	30/10/2014
Remarks	---

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1 Introduction

Internal and external training activities represent a mandatory cornerstone for the creation of a European community able to support the realization of EISAC (European Infrastructures Simulation & Analysis Centre) and to exploit its functionalities. CIPRNet will arrange specific training activities aiming to provide basic and advanced knowledge about Critical Infrastructure MS&A (Modelling, Simulation and Analysis) targeted to a broad range of personnel related to CI (including, but not limited to, local administrations, utilities personnel, emergency operators and managers, security & safety operators and managers, CIP researchers, CIP policy makers, etc.).

This deliverable describes in details the first course inside the Post Graduate Master in Homeland Security in terms of training materials, scheduling and attendees' feedback monitoring.

The courses inside the Post Graduate Master in Homeland Security consist of three training editions scheduled for 2014, 2015, and 2016 in Rome.

The courses consist of a generic part for each episode, treating with elementary knowledge in MS&A (repeated at each episode), followed by a more advanced part specified as following:

- ✓ Episode 2014: Federated Simulation and Open MI platform
- ✓ Episode 2015: Decision Support System (DSS)
- ✓ Episode 2016: What-if Analysis

During the course, the attendees also have the chance to practice with the tools developed within the CIPRNet project in accordance with federated simulation, decision support systems and 'what if' analysis.

This approach will certainly foster the new generation of risk assessment/management tools, which will enable an easier and more effective management of crises.

This document will present the activities performed for the first course on Modelling, Simulation and Analysis of Critical Infrastructures inside the postgraduate Master in Homeland Security.

The structure of this document is composed of two sections: the first section presents the course in terms of venue, programme and attendees. The Appendixes collect the material prepared for the course and/or collected during the course.

1.1 Acronyms

Acronym	Explanation
CI	Critical Infrastructure
CIP	Critical Infrastructure Protection
CIPMA	Critical Infrastructure Protection Modelling and Analysis
CIPRNet	Critical Infrastructure Preparedness and Resilience Research Network
CISIA	Critical Infrastructure Simulation by Interdependent Agents
DB	Database
DIESIS	Design of an Interoperable European Federated Simulation Network for CI
DSS	Decision Support System
EISAC	European Infrastructures Simulation & Analysis Centre
EU	European Union
FP	Framework Programme
FR	Functional Requirement
GIS	Geographic Information System
GPS	Global Positioning System
I2SIM	Infrastructure Interdependencies Simulator
IIM	Input Output Inoperability Model
MS&A	Modelling, Simulation and Analysis
NFR	Not Functional Requirement
NISAC	National Infrastructure Simulation and Analysis Center
OpenMI	Open Modelling Interface
PA	Public Authority
PSF	Participant Satisfaction Form
QoS	Quality of Service
RAFI	Risk Assessment Forecast Interval
S&A	Simulation and Analysis
VCCC	Virtual Centre of Competence and expertise in CIP
V&V	Verification and Validation

2 Course inside the Post Graduate Master in Homeland Security

The course on Modelling, Simulation and Analysis of Critical Infrastructures has confirmed the importance to pursue training activities within the project. Lecturers have had the opportunity to strongly cooperate with attendees during this 2-day event, which topics have been roughly the same ones of those addressed in the Edition 1 of the Master Class (Paris, 24–25 April 2014). Similar to the previous training event, the scheduling of this event has been slightly modified in order to meet speakers' needs and attendees' feedback to adopt a similar logical sequence of the lectures.

The present deliverable aims to illustrate the first edition of the course held inside the Post Graduate Master in Homeland Security with a considerable focus on the audience's feedback.

The Course provides a challenging learning environment where research endeavours are applied to real-world challenges associated with man-made and natural emergencies and critical incidents on the local, national, and global levels.

Teachers bring their diverse professional, disciplinary, and cultural backgrounds into the learning processes.

2.1 Venue

The Course on Modelling, Simulation and Analysis of Critical Infrastructures has been held at the University Campus Bio-Medico of Rome, Rome (Italy) on 10th - 11th July 2014, and the event was organized by the same institution, inside the Post Graduate Master in Homeland Security.

Figure 1: Venue of the course, UCBM

2.2 Program

The program of the course is based on the design of the general training course, as described in D9.1 CIPRNet training Plan [chapter 2.2] and taking into account the results of the participant satisfaction forms collected during the previous internal CIPRNet Course (Delft, 3-4 February, 2014) and the Edition 1 of the Master Class (Paris, 24-25 April, 2015).

The program is particularly focused on the challenges of a supply chain in the context of potential infrastructure failures.

Security is one of the fastest growing challenge in the world today, with applicability in a wide set of different industries and fields, such as services, infrastructures, government and business. The competences provided in the Post Graduate Master give the chance to the students to branch out into other areas, and develop skill sets that are unique.

Because the course of Modelling, Simulation and Analysis of Critical Infrastructures covers a broad area of topics, the Post Graduate Master in Homeland Security tends to focus on the dynamics of technological innovation and the need of adaptive behavior of businesses and markets. Within these dynamics it is possible to narrow the focus even further and learn the skills necessary to work in one of several emerging or well-established industries.

The detailed program is shown in Appendix A.

2.3 Attendees

The course inside the Homeland Security Post Graduate Master was attended by 20 participants. The audience consisted of the students of the Master in Homeland Security and is particularly appropriate for the aim of the course, as it is designed for young security managers, public authorities' representatives, young security or CIP researchers, and law enforcement officers.

Similar to the Master Class, the aim of this course is to prepare next generation security managers and experts to the use of instruments as those provided by CIPRNet and by the VCCC. Moreover, this event contributes to acquire feedback on the training materials and on the VCCC services for heterogeneous end-users: public authorities who can take advantage of the skills acquired on the job as well as representatives of private companies who can use the arguments within the company. The need for qualified professionals is expanding at national and local levels, as well as internationally, so a homeland security education portfolio suits the needs of many individuals working in this field and fosters national as well as international careers.

The list of all the attendees is reported in Appendix C. All the attendees received a "Certificate of Attendance" whose template is reported in Appendix D.

Figure 2: Group of participants

Figure 3: Classroom and audience view

2.4 Feedback

The effectiveness and the quality of the training have been evaluated on the basis of the feedback received from the attendees. To this end, a specific Participant Satisfaction Form (PSF) has been elaborated and submitted to all the attendees.

On the basis of 8 collected PSFs the result was that the expectations of the attendees have been fully covered, and the overall satisfaction was very high.

The feedback of this course confirmed the results of the Edition 1 of the Master Class in Paris, regarding the valuable opportunity to interact with experts and to acquire expertise regarding CIPRNet software tools.

Thanks to the proactive interest of the participants, several suggestions and contributions to the lectures quality were given also during the course itself, allowing for the improvement of the lectures' clarity with respect to their academic and technological aspects for future editions.

Various suggestions are also reported in the PSFs (see Annex E).

Finally the PSFs highlighted that the course has covered the expectation of the audience for almost all participants in terms of time scheduling, logistic facilities and content. Figure 4 reports the results of the PSFs for the general aspects of the course, evaluated in a scale from 0 to 5.

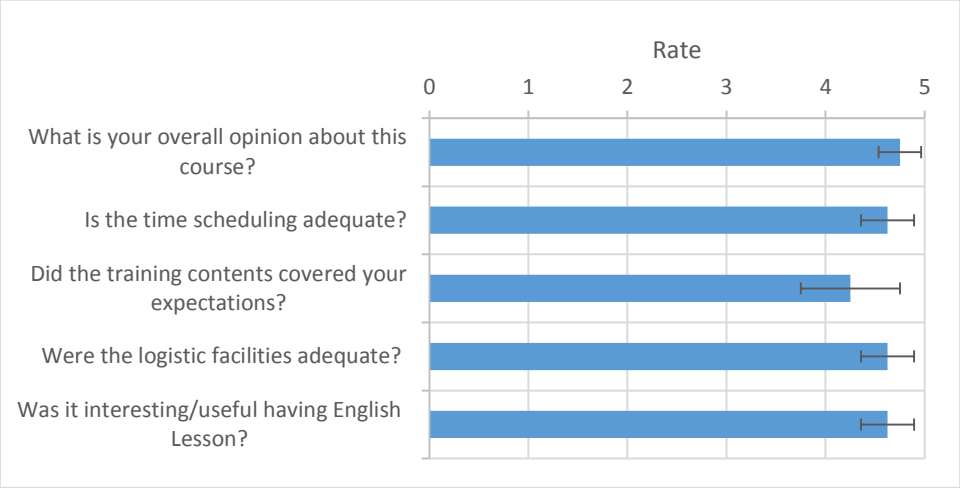


Figure 4: Data collected from Participant Satisfaction Forms on general aspects.

The PSFs also collected opinions regarding any specific lecture, with the same rating scale, and with open comments. These specific comments have been addressed to the related speaker, in order to improve the effectiveness of each lecture.

The Figure 5 shows the average values of the scores obtained by each lecture of the course.

Note that evaluations are quite positive for all speakers and scores range from a minimum value of 4.3 to a maximum value of 4.6.

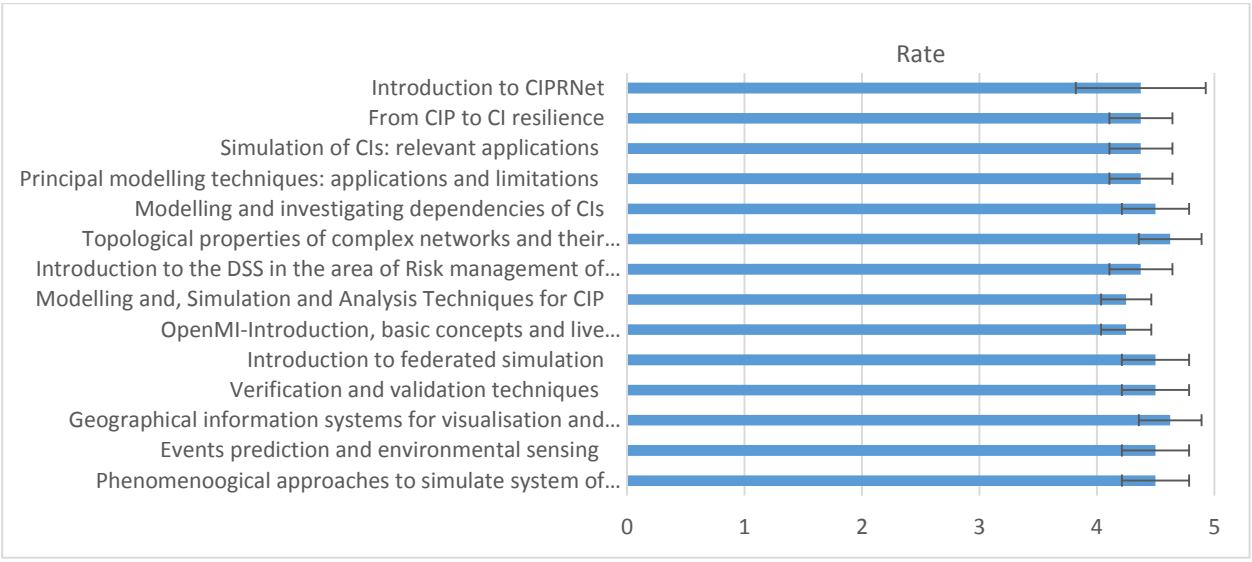


Figure 5: Data collected from Participant Satisfaction Forms on each lesson.

This valuable information will be used, similarly to the past training courses, to improve the training material, scheduling, organization, and focus for the following editions.

Detailed general comments provided by attendees have been collected and reported in Appendix E.

2.5 Comments

In conclusion, the Course on Modelling, Simulation and Analysis of Critical Infrastructures inside the Post Graduate Master in Homeland Security has been successfully carried out, explaining and clarifying the project's approach challenging the critical infrastructures protection context.

In the course, as occurred during the Master Class in Paris, there was a great interaction between attendees and teachers, exchanging valuable and constructive ideas.

Finally, as described in details in this document, the objectives set by the course have been achieved.

2.6 How data collected from Participant Satisfaction Forms have improved the course

The first edition of the Master Class with all feedbacks received by PSFs has represented an extensive source of suggestions for improving the quality level of the course. To be attentive to feedback from attendees is extremely important in order to improve the level of training activities for the next events.

Hence, from the analysis of the several PSFs collected after the Edition 1 of the Master Class some recommendations were very useful for improving the course inside the Post Graduate Master in Homeland Security.

In particular, some of the lessons have been expanded, following the indications related to the interest in particular topics and giving more time to better explain some basic concepts and for discussions.

More attention has been given to exercises due to the appreciation expressed in the PSFs of the Master Class in Paris.

Some other changes in the program have been applied due to teachers' availability matching t time scheduling.

The high quality reached by the Master Class in Paris has been confirmed by the feedback received within this course, satisfactorily meeting the expectations of the attendees.

Appendix A – Programme

CIPRNet

Critical **I**nfrastructure **P**reparedness and **R**esilience Research **Net**work

Course on Modelling, Simulation and Analysis of Critical Infrastructures

PROGRAMME

DAY	TEACHER	TOPIC	
10 July	*Registration and welcome coffee*		*9:30 – 10:00*
	R.Setola	Welcome	10:00 – 10:10
	E. Rome (Fraunhofer)	Introduction to CIPRNet	10:10 – 10:50
	M.Theocharidou (JRC)	From critical infrastructure protection to critical infrastructure resilience	10:50 – 11:30
	E. Luiijf (TNO)	Simulation of Critical Infrastructure (CI): relevant applications	11:30 – 12:10
	Coffee break		*12:10 – 12:30*
	M. Eid (CEA)	Principal modelling techniques: applications and limitations	12:30 – 13:10
	R. Setola (UCBM)	Modelling and investigating dependencies of CI	13:10 – 14:00
	Lunch		*14:00 – 15:00*
	V. Rosato (ENEA)	Topological properties of complex networks and their relevance for CI	15:00 – 15:40
	V. Rosato (ENEA)	Introduction to the DSS in the area of risk management of CI	15:40 – 16:20
	Coffee break		*16:20 – 16:40*
	E. Rome (Fraunhofer)	Modelling, simulation and analysis techniques for CIP	16:40 – 17:20
	B. Becker and A. Zijderveld (Deltares)	OpenMI – Introduction, basic concepts and live demonstration	17:20 – 18:30
11 July	*Welcome coffee*		*8:45 – 9:00*
	E. van Veldhoven (TNO)	Introduction to federated simulation	9:00 – 9:40
	E. van Veldhoven (TNO)	Verification and validation techniques	9:40 – 10:20
	M. Pollino (ENEA)	Geographical information systems for visualisation and analysis	10:20 – 11:00
	Coffee break		*11:00 – 11:20*
	A. Zijderveld (Deltares)	Events prediction and environmental sensing	11:20 – 12:00
	A.Tofani (ENEA)	Phenomenological approaches to simulate system of systems	12:00 – 12:40
	R. Setola (UCBM)	Discussion and closing remarks	12:40 – 13:00
	Lunch		*13:00 – 14:00*

Appendix B – Training Material

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Introduction to CIPRNet

Erich Rome
erich.rome@iais.fraunhofer.de

Fraunhofer IAIS

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

UCBM Headquarters – Rome (Italy) – 10-11 July 2014

Agenda

1. CIPRNet
2. "Critical" Infrastructures
3. CIPRNet: research context, activities, and new capabilities
4. Modelling, simulation and analysis of CI – setting the frame
5. Summary of CIPRNet introduction
6. CIPRNet's training activities
7. Questions & Answers

1. CIPRNet – Facts

- Critical Infrastructures Preparedness and Resilience Research Network
- Co-funded by: EU FP7
- Instrument: Network of Excellence (NoE)
- Start date: March 1, 2013
- Duration: 48 months

1. CIPRNet – Consortium

1. Fraunhofer IAIS, DE (Coord.))
2. ENEA, IT
3. TNO, NL
4. UIC, FR
5. CEA, FR
6. Joint Research Centre, EU
7. Deltares, NL
8. University of Cyprus, CY
9. University of Technology and Life Sciences, PL
10. Università Campus Bio-Medico di Roma, IT
11. University of British Columbia, CA
12. ACRIS GmbH, CH

2. "Critical" Infrastructures

Definition of Critical Infrastructure according to ECI directive

- "A critical infrastructure (CI) consists of those assets and parts thereof which are essential for the maintenance of critical societal functions, including the supply chain, health, safety, security, economy or social well-being of people." [EU2008]
- European CI (ECI) comprise CI of at least three Member States [EU2008]
- ECI sectors already identified [EU2008]: energy and transport CI
- National definitions vary, for example:
  - Germany: 9 CI sectors
  - The Netherlands: 12 CI sectors
  - France: 11 "activity sectors of vital importance"
- 2013: Review of ECI and EPCIP

[EU2008] European Commission: ***Council Directive 2008/114/EC*** *of 8 December 2008 on the identification and designation of European Critical Infrastructure and the assessment to improve their protection*

[EU2013] European Commission: ***CS Working Document*** *SWD(2013)318 of 28.8.2013 on a new approach to the European Programme for Critical Infrastructure Protection Making European Critical Infrastructures more secure*

2. "Critical" Infrastructures

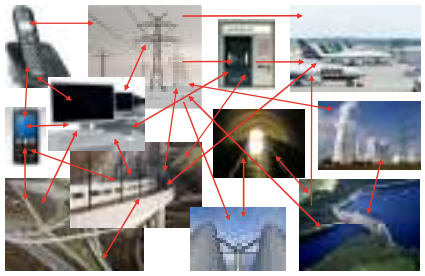
- Since the late 1990s, the CI topic gained importance with the advent of new threats
  - Year 2000 bug
  - WTC attacks on 11.9.2011
  - Climate change
- Follow-up activities
  - Identification of CI
  - Risk assessment of CI, following an **all hazards** approach
  - Measures for protection of CI
  - New research area: Critical Infrastructure Protection (CIP)
- The USA and Europe took different paths

2. "Critical" Infrastructures (CI)

CI

- are complex
- depend on other CI
- extend cross-border
- are continuously changing, adapting to changes in technology, economy, legislation, …

CI form a system of systems



2. "Critical" Infrastructures

Protection, resilience and preparedness

- A 100% safety and security of CI is impossible to achieve
- **In order to protect CI, to make them more resilient, and to maintain their vital societal functions, this super-system needs to be understood**
- Essential for any improvement in resilience or preparedness is a better understanding of CI
  - What CI are affected by a crisis or emergency?
  - What is the role of CI in emergency plans?
  - What CI are needed for supplying, evacuating, caring people affected by a crisis?

2. "Critical" Infrastructures

Insight on CI in crises, catastrophes, and emergencies

- **post mortem analyses** of real CI damages (like Kirchbach report on the Oder flood 2002)
- Real **exercises** (like LÜKEX)
- Computer-based **modelling, simulation and analysis (MS&A)** of crisis scenarios
- **Research results***

CI damage reports

*see presentation by E. Luiijf

3. CIPRNet joint activities

Capability forming
- Providing **new capabilities** to end users for better preparedness for CI-related emergencies:
  - Advanced decision support
  - 'what if ' analysis

Capacity building
- **Building capacities** by educating and training experts and researchers (reaching a critical mass)

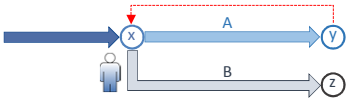
Knowledge & technology
- **Providing knowledge and technology to end users** for improving their understanding of the role of CI in crises and emergencies

VCCC
- Provide **long-lasting support** by establishing a **Virtual Centre of Competence and Expertise in CIP (VCCC)**

3. CIPRNet's new capabilities

CI MS&A modelling for exploring various possible courses of action

- **'what if' analysis:** The exploration of different courses of action and their different consequences
- Compare consequences of courses of action A, B (consequence analysis)



- Which action produces the least consequences? (e.g. duration of outages, number of affected people/businesses)
- Applications include:
  - Training of crisis managers
  - *post mortem* analyses

3. CIPRNet's new capabilities

Advanced Decision Support

- **Decision Support System (DSS)** for supporting Emergency Managers by providing a comprehensive assessment of the behaviour of CIs under severe perturbations
- DSS tasks:
  - Set-up the emergency scenario
  - Evaluate the impact of the disruption of CI elements causing a reduction in the Quality of the delivered Services
  - Provide end users with data and estimates helpful for making accurate scenarios assessment needed for undertaking the necessary decisions for optimal mitigation and healing strategies
- Applications include:
  - Warm and hot phase support of emergency managers and CI operators
  - Training

3. CIPRNet's new capabilities

Virtual Centre of Competence and Expertise in CIP (VCCC)

- How can CIP related research results be transferred into practical application?
- How can support of CIP research experts to end users be sustained?
- First step: VCCC – Role model is NISAC (USA)
- CIPRNet will create the tangible VCCC already during the project term
  - by implementing the CIPRNet agenda and
  - by combining and integrating the excellence in CIP knowledge, expertise, experiences and technology of the partners
- VCCC serves as foundation of the long-lasting European Infrastructures Simulation and Analysis Centre (EISAC)

4. MS&A of CI – the frame

- Computer-based modelling, simulation and analysis of CI involves a complex setup of **multiple CI domains** and **external threats and events**
- There are many simulators, models, and analysis approaches around
- Challenges include:
  - Determination of what should and can be **investigated** using MS&A
  - Getting the required domain knowledge and **data**
  - Transforming this into valid and appropriate **computer models** at the adequate level of fidelity
  - Overcome technical difficulties (like **semantic interoperability**)
  - Performing the required **analyses**
  - Applying **verification and validation** approaches for maximising the validity of the results
  - Developing standardised **workflows for MS&A**

5. Summary of CIPRNet intro

- CIPRNet undertakes a next step towards realising EISAC by capability forming and capacity building
- CIPRNet will deploy new capabilities to its initial audiences
  - Advanced decision support
  - MS&A based 'what if' analyses with consequence analysis
- CIPRNet seeks collaboration with national projects and with end users
- A core element of CIPRNet technologies and of CI(P) related research in general is MS&A

6. CIPRNet's training activities

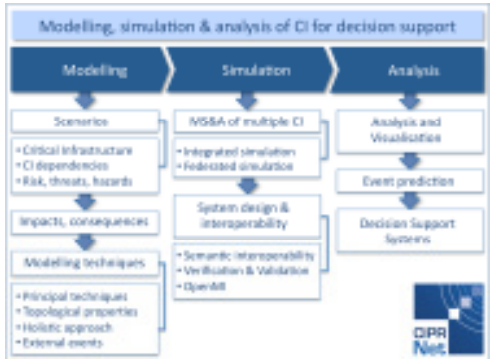
Elements of CIPRNet's training activities

- Internal training
  - Familiarising partners with each other's technology and know-how, fostering coherence
- CIPRNet lectures
  - Disseminating CIPRNet know-how to the CIP research community
- CIPRNet Master Classes
  - Familiarising CIPRNet's target audiences with CIPRNet's essential technologies
  - MC1, 2014: Modelling, Simulation & Analysis of CI
  - MC2, 2015: New CIPRNet capability: Decision Support System
  - MC3, 2016: New CIPRNet capability: MS&A-based 'what if' analysis
- CIPRNet courses in the Postgraduate Master in Homeland Security
  - Educating young researchers in the required multi-disciplinary mind-set

6. CIPRNet's training activities

- Audience
  - Students of the Postgraduate Master in Homeland Security
- Objectives of the first CIPRNet Course in MHS
  - To perform training for the students of the MHS and familiarise them with MS&A of CI and its applications in analysis, decision support, and Crisis Management training
  - To prepare next generation security managers to the use of instruments as those provided by CIPRNet and by the VCCC
- Contents
  - basic concepts about MS&A of CI
  - advanced aspects related to federated simulation
  - use of the Open Modelling Interface (OpenMI)
- Experts from the multi-disciplinary FP7 network CIPRNet will be presenting the lectures

7. Conceptual Map

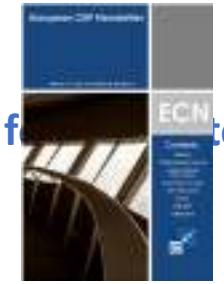


Locating the lectures

8. Questions & Answers

www.ciprnet.eu

European CIIP Newsletter



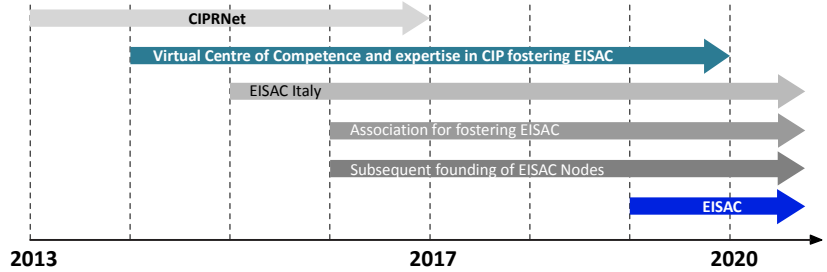
CRITIS 2014

3. CIPRNet research context

- USA: National Infrastructures Simulation and Analysis Center (NISAC)
- Canada: DR-NEP, i2Sim (University of British Columbia)
- EU:
  - Various nationally funded projects
  - Projects funded by Research Framework Programmes and successor
  - Projects funded by the European Programme for CIP (EPCIP) and successors
- Often used methods and tools: MS&A of complex scenarios involving CI and external threats
- Common challenges:
  - Transferring CIP related research results into practical application
  - Sustaining the support of CIP research experts to end users

4. Timelines

Timelines: CIPRNet, VCCC, and EISAC 2020



4. CIPRNet target audiences

- **End-users (initial audience)**
  National and EU emergency management and other public authorities, CI operators and owners
- **Policy-makers**
  private and public sector CIP policy-makers, governmental agencies
- **Research**
  core CIP research centres, individual researchers in CIP and related research areas, academic students
- **Other**
  the population in the EU and nations, CI sector-specific associations

4. CIPRNet boards

Advisory boards and groups

- International Advisory Board provides consultancy
- Internal Security Advisory Group controls privacy of sensitive information
- External Ethics Board guides and assesses compliance with legal and ethical standards

4. Compliance with standards

Independent Ethics Board

- Potential ethics issues of main concern for EU:
  - Data privacy and data protection
  - Dual use
  - Mission/Function creep
- Main goal of taking ethical issues of EU projects into account:
- Ensuring compliance of project results with ethical rules since it is a legal obligation
- Effects:
  - General good ethical conduct
  - Fulfilling the legal obligations
  - Ensuring that tax payers' money is not wasted on project results that must not be used due to ethical issues

4. Security

Security Advisory Group

- CIPRNet's research may produce sensitive information that must not be made public
- CIPRNet has established an internal Security Advisory Group (SAG) of qualified experts
- SAG members check all dissemination material for such information and requires corrective actions, if necessary
- Security assessment is integrated in overall quality management process

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

From critical infrastructure **protection** to critical infrastructure **resilience**?

Marianthi Theocharidou – European Commission, Joint Research Centre
marianthi.theocharidou@jerc.ec.europa.eu

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

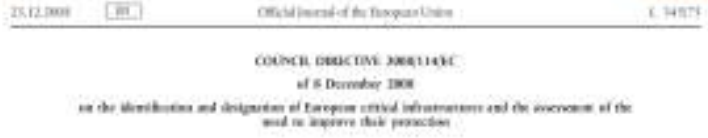
UCBM Headquarters – Rome (Italy) – 10-11 July 2014

Outline

- Protection or Resilience ?
- EU vs. US approach
- Definition(s)…
- Resilience dimensions
  - Societal
  - Economic
  - Organisational
  - Technological

Based on the report:
C. Pursiainen & P. Gattinesi, "**Towards Testing Critical Infrastructure Resilience**", JRC Scientific and Technical Reports, European Commission, Joint Research Centre, 2014.

Definition of CIP



COUNCIL DIRECTIVE 2008/114/EC
of 8 December 2008

- '**Critical infrastructure**' means an asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions.
- '**Protection**' means all activities aimed at ensuring the functionality, continuity and integrity of critical infrastructures in order to deter, mitigate and neutralise a threat, risk or vulnerability.

Protection vs. Resilience

Protection vs. Resilience

- The resilience discourse first started appearing in unofficial policy and scientific analyses in the **mid-2000s** in the context of **crisis** and **disaster management**.
- Focusing on resilience was justified with criticism of official government positions that complete **critical infrastructure protection can never be guaranteed**.
- Moreover, achieving the desired guaranteed level of protection is not **cost-effective** in relation to the actual threats. A small increment in the level of protection might introduce a large amount of additional costs, and therefore alternative approaches need to be considered.

Official EU vs. US approaches on Resilience

- CI Resilience in **USA**:
  - emerged first from **2006** onwards
  - primarily treated as a **subset** of protection (2006 NIPP)
  - based on **voluntary** public-private partnerships
- CI Resilience in **Europe**:
  - appears **around 2010-2012** in policy documents
  - somewhat stronger emphasis on (national) **regulation**
  - Is now considered **cross-sectoral**
- In both cases, the focus has mostly been in **organisational** and **community** resilience **measures**, although some **technological resilience** issues have more recently been brought forward, particularly in the US.

Definition(s)?

- The US Presidential Policy Directive on Critical Infrastructure Security and Resilience from February 2013 defines resilience as follows:
  - *"The term '**resilience**' means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."*

Definition(s)?

- The EU does not have any "official definition" of CI resilience; some Member States have it however in their policy documents.
  - ***Resilience*** *(in the UK) is the ability of assets, networks and systems to anticipate, absorb, adapt to and / or rapidly recover from a disruptive event.*

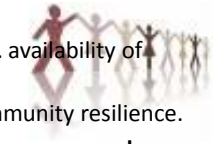
Dimensions of resilience

- The exact boundaries of the 'resilience discourse' are still rather obscure
- However, sub-discourses or research sub-fields and partially shared definitions have emerged and even become institutionalized.
- At least four different dimensions of critical infrastructure resilience:
  - **Societal resilience**
  - **Economic resilience**
  - **Organisational resilience**
  - **Technological resilience**

Other 'dimensions' found in the literature: 'functional resilience', 'personal resilience'; 'physical resilience'; 'planning resilience'; 'ecological resilience'; 'socio-ecological resilience'

Societal resilience

- '**Societal**', '**regional**' or '**community**' resilience - often used interchangeably
- Refers to empowering the whole society, including **local communities** and **businesses**, rather than only enhancing the authorities' crisis management capacities or control.
- Refers to the society's **survival** and **recovery** strategies, e.g. availability of shelters, time to restore lifeline services, etc.
- There is **no universally agreed definition** of societal or community resilience.
- While good practices of resilient communities exist, there are **no agreed methodologies or metrics** on how to test community resilience.
- From the critical infrastructure point of view, the concept is not very helpful.



Economic resilience (1/2)

- Focus on the **dynamics** of technological innovation and the need of adaptive behaviour of **businesses** and **markets**.
- Consequently, emphasis on issues such as
  - the extent of regional economic diversification,
  - the ability to substitute and conserve necessary inputs,
  - business and industry capacity to improvise, and
  - the time needed to regain capacity or lost revenues.

Economic resilience (2/2)

- **Static economic resilience** is "the ability of an entity or system to maintain function (e.g., continue producing) when shocked".
- **Dynamic economic resilience** "is the speed at which an entity or system recovers from a severe shock to achieve a desired state."
- Recently, this field of study has been focusing on developing resilience indicators or an overall resilient index to characterize economic resilience at different economic 'levels'.
  - microeconomic (individual business or household)
  - mesoeconomic (individual industry or market)
  - macroeconomic (combination of all economic entities)

Organisational resilience (1/3)

- Concept applied to crisis management and civil protection systems.
- One basic way to enhance organisational resilience is through training and preparedness.

Example: For **electricity supply disruptions**, **operators** need to:

- Make plans of how and when personnel should be called in, or put on stand-by
- Keep maps up to date
- Maintain information about how disruption affects operations
- Monitor weather forecasts
- Make arrangements with third parties for providing spare parts and additional equipment
- Prepare for cooperation with the emergency services,
- Find out vulnerabilities in telecommunication nodes, waterworks and sewage farms
- Prioritize support for vulnerable groups such as hospitals, nursing homes for older people, schools, day-care centres etc.

Organisational resilience (2/3)

- Organisational resilience also connects the resilience concept to the concept of **business continuity**.
- In more general terms, this literature is very much focused on the challenges of the **supply chain** in the context of potential infrastructure failures. The first resilience standards are related to this issue.
- The **ISO 28002** standard for resilience in the supply chain was approved in 2011, based on the United States ANSI/ASIS organisational resilience standard.

Organisational resilience (3/3)

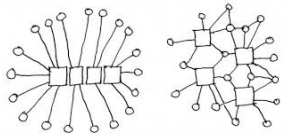
- ISO 28002: "[…] requirements for a resilience management system to enable an organization to develop and implement **policies**, **objectives**, and **programs** taking into account legal requirements and other requirements to which the organization subscribes, information about significant **risks**, **hazards** and **threats** that may have an **impact** on it (and its stakeholders'), and **protection** of critical assets (human, physical, intangible, and environmental."
- Focus on a proper risk management system embedded in the organization, including such elements as training, risk assessment, prevention, mitigation etc.

Technological resilience

- Technological resilience is more **about the infrastructure** itself, rather than about the society around it, or the economic consequences of its disruption, or the organisation ensuring the functioning of the infrastructure
- Technological resilience can be to some extent enhanced, measured and tested by looking at its (overlapping) '**components**'
  - **Resilient design**
  - **Avoiding harmful dependencies and interdependencies**
  - **Redundancy**
  - **Restoring capability**

Resilient design (1/2)

- '**Resilient design**', '**resilient engineering**', '**reliability**', '**robustness**', or '**absorptive capacity**' are largely overlapping terms.
- The safety and security factors should be built-in to the systems so that the **systems** would then be better capable of **absorbing** or **withstanding disturbances**, thereby minimising the consequences.



Resilient design (2/2)

- E.g. a system build from modules, so that when one component fails, the failed component can be easily replaced or its functions switched to another component.
- It is however difficult in advance anticipate all the risks and design accordingly. Some theoretical treatments emphasize that failure data from real-life cases are especially important for examining the resilience of systems and using these results in developing strategies to improve design.

Avoiding harmful dependencies and interdependencies (1/2)

- A **dependency** in this context is understood as a unidirectional relationship from one infrastructure to another. Thus, the state of one infrastructure influences or is correlated to the state of the other, but not vice versa.
- An **interdependency** is a bidirectional relationship between two (or more) infrastructures, meaning that the state of each infrastructure influences or is correlated to the state of the other(s).
- A resilient critical infrastructure should not be such that, even if it would be robust itself, it would become easily dysfunctional due to dependencies or interdependencies between it and other related infrastructures or systems.

Avoiding harmful dependencies and interdependencies (1/2)

- It is difficult however to test these complicated dependencies and interdependencies in an operational environment (without causing too much harm).
- Therefore, in most cases the only feasible methodology to study and test dependencies, interdependencies and cascading effects is to focus on **modelling** and **simulations**.

Redundancy (1/2)

- '**Redundancy**', '**interoperability**', '**adaptive capacity**' and '**resourcefulness**' are some of the concepts used in resilience debates to emphasize the *degree* that the function of a system temporarily disturbed can be replaced by other systems, substituted by other solutions, re-routed etc.
- Basically redundancy presupposes the **duplication** or **triplication** of critical elements of a system with a **backup**, and therefore an individual component or function failure would not be enough to put the system down. The duplicated systems in turn should not be connected e.g. with a shared one vulnerable point.

Redundancy (2/2)

- **Passive redundancy** allows an element to fail while the main functions remain in tact though the performance decreases, e.g. human eyes.
- **Active redundancy** monitor and detect e.g. overload in one power line and circuit breakers should automatically disconnect this line and redistribute the power across the remaining lines.

Restoring capability

- '**Restoring capability**' is basically the same concept as '**recovery**' or '**rapidity**' used in many occasions.
- Two basic ways to measure resilience from restoring capability point of view that could provide a basis to develop more operationalized test schemes for critical infrastructure systems
  - To measure the **amount of time** (or money/losses) it takes for an infrastructure or a function to recover fully to normal operations
  - To measure the **performance**, that is, whether the system was put out of operation completely or not.

Summing up

- Technological resilience can be enhanced, measured and tested

What could be tested?	How should it be tested?
Resilient design (cf. resilient engineering, reliability, robustness, resistance, absorptive capacity)	e.g. tests of the resiliency of a component or a system based on real failure data
(Inter)dependencies	e.g. computer-based modelling and simulation
Redundancy (cf. interoperability, adaptive capacity, resourcefulness)	e.g. passive and active redundancy testing
Restoring capability (cf. recovery, rapidity)	e.g. calculating the amount of resources (times, money) the recovery takes, or measuring the ration of lost performance/total performance

Thank you!

Questions or comments?

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Simulation of Critical Infrastructures (CI): Relevant Applications

Eric Luiijf, TNO
eric.luiijf@tno.nl

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

UCBM Headquarters – Rome (Italy) – 10-11 July 2014

Agenda

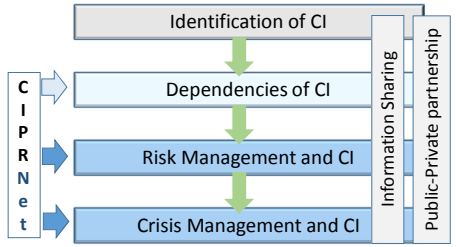
- Application of Modelling, Simulation & Analysis in CIP
  - different areas of application
  - added value for stakeholders
- Existing activities
  - USA: NISAC / HITRAC
  - Australia: CIPMA
  - CIPRNet consortium: I2SIM, DIESIS toolset, CISIA, more …
- Looking forward
- Questions/discussion

Objectives of this lesson

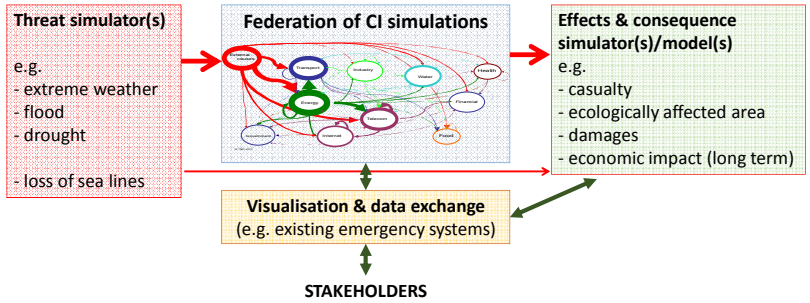
- Understand
  - the different areas of application of CIP Modelling, Simulation & Analysis (MS&A)
  - the added value for stakeholders such as policy-makers, CI operators, emergency management (exercises, what-if, decision support)
- Understand the current international activities in CIP MS&A and future directions

Main focus areas of Critical Infrastructure Protection (CIP)

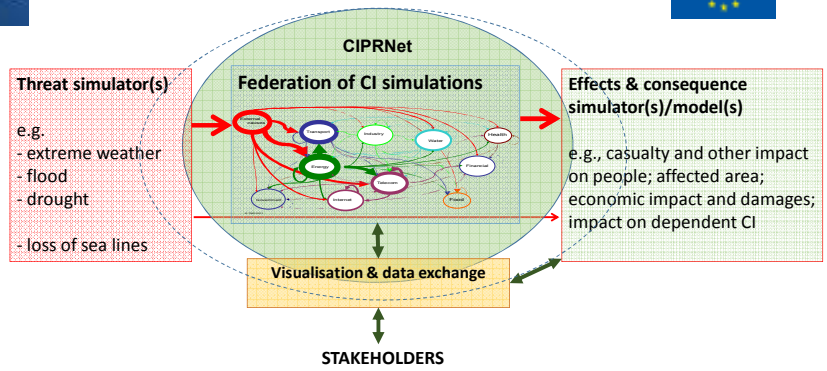
- CIP in the EU and its Member States
  - various Member States since 2002, EU started around 2004
  - some of the main action lines of the European Programme on CIP (EPCIP) may be supported by MS&A



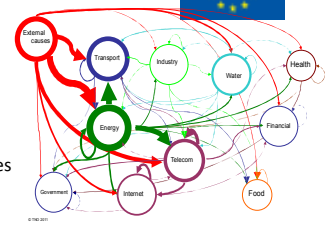
CI MS&A – What is it all about?



CI simulation – What is it all about?



Application of MS&A in CIP – why?



- To analyse complex CI dependencies
  - different **modes of operation** of CI with other less known sets and strengths of dependencies
  - cascading effects with various **disruption & recovery characteristics**; QoS - SLAs
  - **common mode failure**: simultaneous disruptions & combinations of CI cascades
- MS&A required for such analysis as
  - 1st order dependencies are simple: after x hours, y will happen
  - more complex effects are hard for humans to assess and present **surprising outcomes other than the 'pre-programmed' outcomes we all know**

Application of CIP MS&A (2)

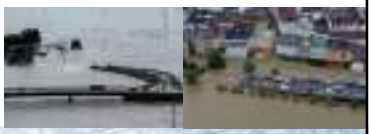
- CIP MS&A may support **but has to prove its added value for stakeholders**
  - risk analysis and risk management (pro-action, prevention, preparation)
  - crisis management and response (prepare/exercises, response, recovery, aftercare)
  - CI resilience (CI design, what-if analysis, exercises)
  - design of Next Generation Infrastructure

Risk analysis and CI

- Risk analysis (pro-action, prevention, preparation)
  - identifying risk scenarios and their impact on CI
  - all hazards, e.g. flooding, earthquakes, extreme weather, cyber attacks & failures, …
- CIP MS&A may help to assess the impact of different "what-if" scenarios and the effectiveness of countermeasures

Crisis Management and Response & CI Operators

- Crisis management and response (prepare, response, recovery, aftercare) of crisis response organisations & CI operators
  - identify which CI may be affected (next)
  - assess the impact of possible (sequences of) events
- MS&A may help to
  - assess effects of hazards on CI
  - assess effectiveness of countermeasures
  - perform a QUICK first order assessment
  - prepare decisions
  - identify lessons / better decisions by 'replay'



Agenda

- Application of Modelling, Simulation & Analysis in CIP
  - different areas of application
  - added value for stakeholders
- Existing activities
  - USA: NISAC / HITRAC
  - Australia: CIPMA
  - CIPRNet consortium
- Looking forward
- Questions/discussion

Activities: USA NISAC / HITRAC (1)

- US National Infrastructure Simulation and Analysis Center (NISAC)
  - Department of Homeland Security (DHS) as partner & sponsor
  - Sandia National Laboratories (SNL)
  - Los Alamos National Laboratory (LANL)
- Mandate and tasks
  - Congress mandated that NISAC serves as "*source of national expertise to address critical infrastructure protection*" research and analysis
  - NISAC prepares and shares analyses of CI including their dependencies, vulnerabilities, consequences, and other complexities
- Budget: 20 M$/year

Activities: USA NISAC / HITRAC (2)

- NISAC has developed large-scale CI models and data sets to support decision-making **before and during** emergencies
  - assist in emergency management at various levels of authority (county, state, federal)
  - analyse the impact of possible scenarios
  - assess the effectiveness of possible mitigating measures
  - support of (national) crisis management in **hot phase** (HITRAC)
- Models supported HITRAC during major emergencies
  - Katrina and Rita hurricanes (2005)
  - Superstorm Sandy (2012)

Activities: Homeland Infrastructure Threat and Risk Analysis Center (HITRAC)

DHS
- Office for Infrastructure Protection
- Office of Intelligence and Analysis (OIA)

with NISAC

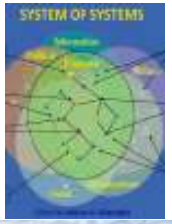
ALL HAZARDS

. prevention planning
. hot hazard analysis
. response planning
. base camp planning
. staging area

Source: DHS/HITRAC

Activities: USA Hampton Roads (Prof. Adrian Gheorghe, Old Dominion Univ.)

- Detailed modelling of transport, shipping, … (major container port; main naval port)
  - in support of (all hazard) emergencies, hurricane lane is one of them
  - planning evacuation routes
  - support crisis management
  - much is detailed operational & crisis management information (thus classified)

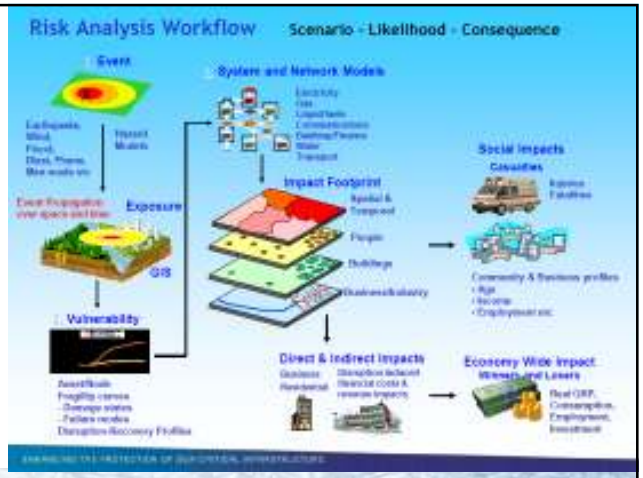


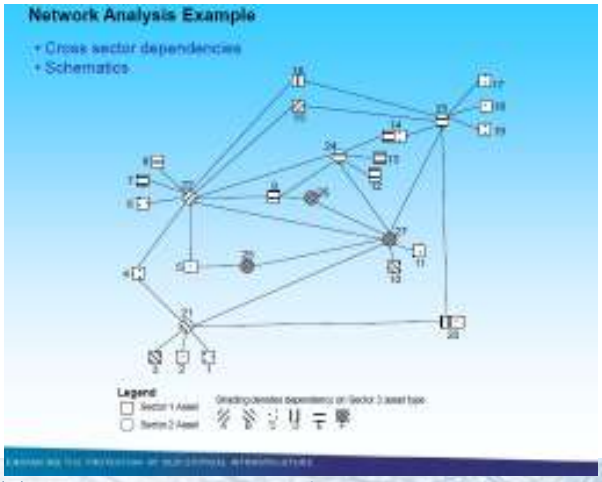
Activities: Australia CIPMA (1)

- AUS GOV Critical Infrastructure Program for Modelling and Analysis (CIPMA)
  - *governmental facilitation* of cross-sector analysis of the AUS CI sectors in a *joint public-private* approach *to increase CI sector resilience*
  - (single) sector by sector but stimulates inter-sector resilience studies
- Modelling capability is used to support CI sectors
  - strategic studies, fast turn-around analysis
  - *only* at request of a critical sector
- Budget: 23.4 M$ (16 M€) for 4 years plus (in kind) by sector(s)

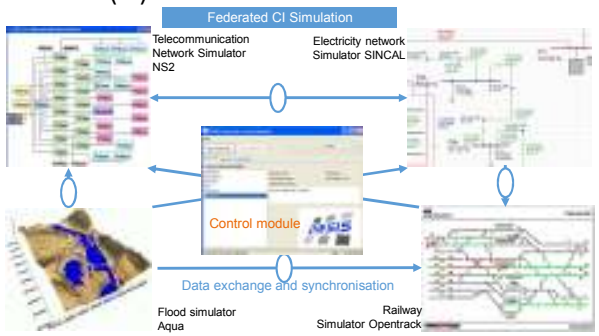
CIPMA

- CIPMA MS&A
  - reusability
  - consistency over time





Activities EU CIPRNet consortium: DIESIS (1)

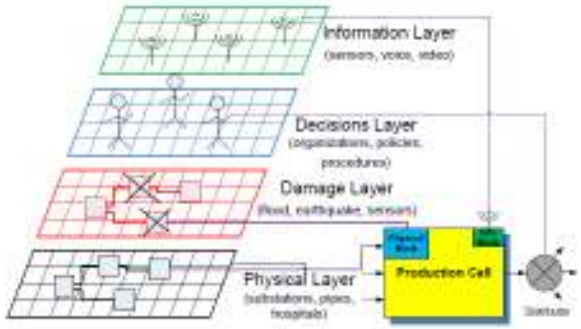


- details: see afternoon presentation by Erich Rome

Activities EU CIPRNet consortium: DIESIS (2)

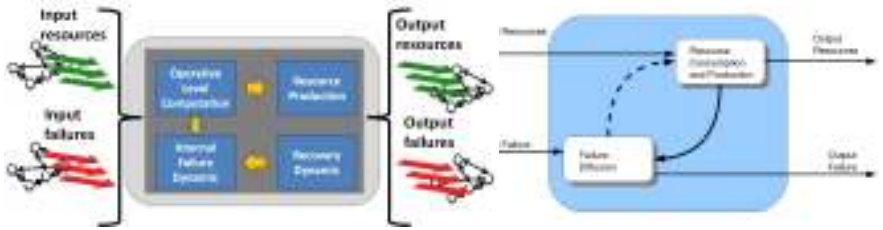
- Example of analyses
  - visualisation of cascading effects
  - black lines indicate disrupted parts of the CI networks

Activities EU CIPRNet consortium: I2SIM



Activities EU CIPRNet consortium: CISIA

Critical Infrastructure Simulation By interdependent Agents (CISIA)
see Roberto Setola's lesson



Activities EU CIPRNet consortium – some other toolsets

Successful MS&A requires more than building a model …

- DATA, DATA, DATA
  - collecting data requires a large effort
  - issues: how to collect CIP information
    how to protect this (often sensitive) information
    artificial data === realistic data ==== real data
- Acquiring sensitive CI operator data requires trust-building, but
  - some information is in the public domain
  - some models do not require fine grained data
  - governments may stimulate data availability

Successful MS&A requires more than building a model … (2)

- Public-private partnerships
  - collaboration between emergency management and CI operators is necessary
    "do not exchange a business card during an emergency"
  - added value of (longer-term) MS&A (investment) shall be clear for stakeholders
  - trust in each other and security arrangements to share valuable information

Looking forward

- CIPRNet is working towards a common MS&A toolset & (demo) data sets
  - based on good practices of e.g. NISAC
- CIP MS&A to assess the robust design of NGI, e.g. smart grids
- Coupling cause models with consequence/effects analysis models via CI models
- Metrics
  - economic impact (non-produce, damages)
  - how many people where in the impacted area? ➔ impact on evacuation, housing, psychological impact & behaviour of people, …
  - how many animals where in the impacted area? ➔ impact

➔ requires standard interfaces between components & GIS-based visualisation

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Introduction to MS&A of CIP

Mohamed Eid – CEA/DANS/DM2S
mohamed.eid@cea.fr

Modelling, Simulation and Analysis of Critical Infrastructures
Master Class (Edition2)

Università Campus Bio-Medico di Roma, Rome (Italy) – 09-10 July 2014

What is the issue?

Understanding the behaviour of critical infrastructures, their dependences and their interdependences.

Developing advanced modeling and simulation methodologies & technologies

Enhancing the CIs' robustness and resilience against threats

Dependence & (Inter)dependence

- Physical/Structural
- Functional
- Procedure

Conceptual Models (1)

▪ Fluid Mechanics	:	**Navier-Stockes Equation**
▪ Heat Transfer	:	**Newton Equation**
▪ Electro-magnetic propagation	:	**Maxwell Equations**
▪ Electrical Circuits	:	**Kirchhoff's Law**
▪ Structure Dynamic	:	**Equations of motion / (Lagrange's Equation, …)**
▪ Neutron transports	:	**Boltzmann Equation**
▪ ……		

Empirical & Statistical Models (2)

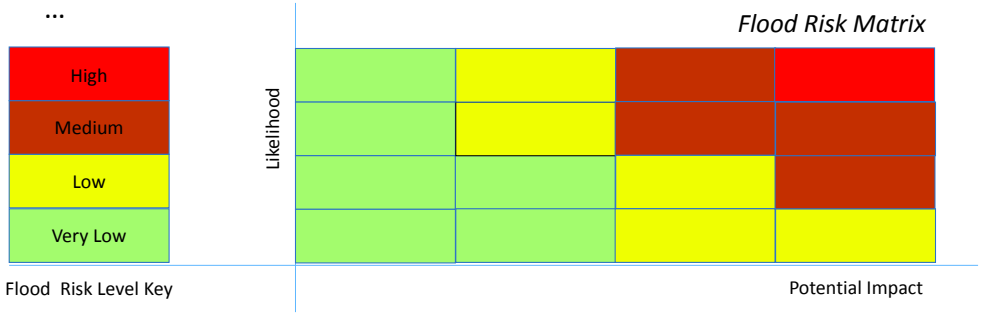
- Rains Flow & Distribution
- Wind Velocity & Direction Distribution
- Loss of Pressure in Pipes (in case of turbulent flow)
- Radiative Heat Transfer (Stefan's Law)
- Traffic & Road Accidents
- Components & Systems Failures
- Detection & Monitoring Failures
- ……

Logical/Relational Models (3)

- Boolean models: minimal cut-sets, critical paths and disjoint cut-sets, conditional gates
- Sequential logical models: Event "E" occurs if Events "A" AND "B" AND "C" occur in that order: sequence analyses
- Fault Trees/Dynamic Fault Trees
- Event trees
- Decision Trees
- Reliability Block Diagrams
- Graphs (networks, states & transitions)
- ……..

Qualitative & Descriptive Models

- Systems' behaviour, state, transition or reactivity are described using qualitative metrics: high/low, much/less, strong/weak, probable/rare …



Simulation

- ***The easy job :*** is to describe the behavior (in space and time) of any system whose functioning involves any of the previous models
- ***The hard job :*** is to describe the behavior (in space and time) of any system whose functioning involves many of the previous models (multi-scale, multi-physics, varying relational)
- ***The hardest :*** is to describe the behavior (in space and time) of any system whose functioning involves many of the previous models, mixing logical, deterministic and probabilistic models

System Complexity

Simulation of Complex Systems

- Needs for Integration Tools
- Integration at different levels of models: Data level, application interface level, method level, and the user interface level
- Stochastic Integration Tools: Monte-Carlo Simulation, Petri-Net & Stochastic Petri-Net, Genetic Algorithms, …
- Smart Agents: active, proactive and social

Recall the Issue

Understanding the behaviour of critical infrastructures, their dependences and their interdependences.

Developing advanced modeling and simulation methodologies & technologies

Enhance CIs' robustness and resilience against threats

Robustness & Resilience

In his report, Sir Michael Pitt, defined resilience "Resilience is the ability of a system or organisation to withstand and recover from adversity."

- Quantitative Modelling? [*to be developed*!!!]
  - Robustness $\propto \Delta 1$
  - Resilience $\propto 1/\Delta 2$
- Qualitative Modelling? [*Sir Michael Pitt, "A comprehensive review of the lessons to be learned from the summer floods of 2007". Final report, June 2008.*]

CIP vs Risk Management?

- The 3RG Focal Report, [*], argues that there are three main conceptualizations of the risk-resilience relationship in the theoretical literature and in CIP-policy documents: resilience as the goal of risk management, resilience as part of risk management and resilience as alternative to risk management.

* *3RG Report Focal Report 7 SKI, "Focal Report 7: CIP Resilience and Risk Management in Critical Infrastructure Protection Policy: Exploring the Relationship and Comparing its Use." Risk and Resilience Research Group Center for Security Studies (CSS), ETH ZürichZurich, Commissioned by the Federal Office for Civil Protection (FOCP), December 2011*

CIP vs Risk Management: resilience as the goal of risk management (1)

Resilience Oriented Risk Management

Resilience would be described as the overarching goal of protection policies and risk management as the method to achieve this goal. *Resilience replaces or complements the concept of protection,* which was previously defined as the goal of risk management activities.

CIP vs Risk Management: resilience as the goal of risk management (2)

Comprehensive Resilience Risk Management

Resilience is understood as a part of risk management. Activities to strengthen resilience are needed in order to deal with the so-called "remaining risks", i.e. risks that have not been identified or underestimated and are thus not covered by appropriate protection (preventive) measures.

But a systematic resilience approach is still to be developed and it seems as if it can't be deterministic, probabilistic, ..

CIP vs Risk Management: Replacing Risk Management (3)

Alternative to Risk Management

Challenges the traditional methods of risk management and promotes resilience as a new way of dealing *with* risks in a complex environment. It is argued that a probabilistic risk analysis is not an adequate approach for socio-economic systems that are confronted with non-linear and dynamic risks and are themselves characterized by a high degree of complexity. Instead of preventing risks and protecting the status quo, such systems should enhance their resilience by increasing their adaptive capacities.

But again! What is Resilience?

Since resilience is defined as the ability to resist, absorb, recover or adapt to adversity of changes in conditions, it is obvious that the concept is related to risk management – as the concepts "adversity" and "changes in conditions" can be described as risks.*

* *UK Cabinet Office, "Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption from Natural Hazards". Publication date: March 2010.*

Remind Our Ultime Goal

The main goal is

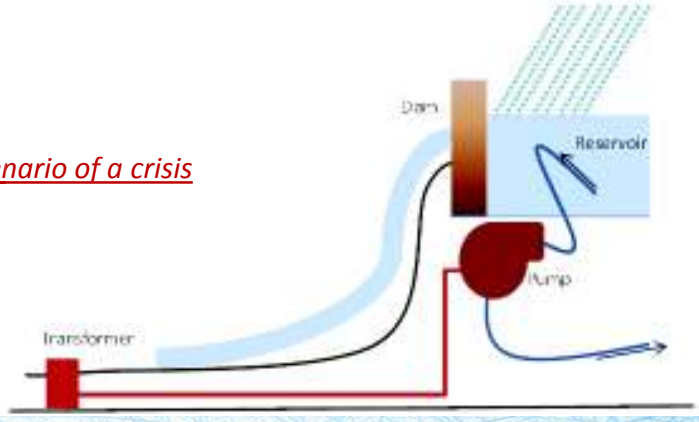
- to identify and assess risks associated to a well-defined threat

And to develop a range of options to;

- eliminate,
- reduce,
- transfer,
- accept or
- share those risks.

Practically Speaking: A hypothetical Case

A hypothetical scenario of a crisis



The threat & involved events

- E1 : Heavy rains (the quantity and the duration). *Probabilistic Model*
- E2 : Static head growth rate. *Deterministic Model*
- E3 : Aged structure (mechanical degradation). *Semi-Deterministic Model*
- E4 : Emergency Pumping Station (EPS) failure. *Probabilistic Model*
- E4 : EPS feedback control loop system. *Probabilistic Model*
- E5 : Power Supply Line (PSL), from the valley. *Deterministic+Probabilistic Model*

How to Simulate this crisis in view of a Decision Making action?

The issue now is:

- To integrate all the models describing; threat, systems' behaviour, sensors, control systems and the potential (inter)dependence.
- To simulate the evolution of the crisis in the time (dynamic)
- To iterate the simulation in order to better identify the worst paths the crisis evolution may take (what if?)
- To assess the ultimate consequences of each possible path.
- To assess the decisions to be made in order to: intercept the threat, reduce, mitigate, accept or share the corresponding Risks

Thanks for attention

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Critical Infrastructure Preparedness and Resilience Research Network

Modelling and investigating dependencies of CI

Roberto Setola (UCBM)
r.setola@unicampus.it

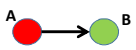
Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

UCBM Headquarters – Rome (Italy) – 10-11 July 2014

Objectives of this lesson

- What is the relevance of (inter-)dependencies?
- How to model these phenomena?
- Which are consequences if we neglect to capture them?

Dependency vs. interdependency



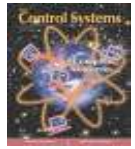
Dependency: is the capability of an infrastructure to influence the state of an other infrastructure. It is a *unidirectional* relationship.

Interdependency: is a *bidirectional* relationship between two infrastructures through which the state of each infrastructure is influenced or is correlated to the state of the other.

Notice that in literature, with an abuse of notation, the term "Interdependency" is used with a broad meaning absorbing in part the "dependency" meaning

Dimensions for describing infrastructure inter-dependencies

September 2011

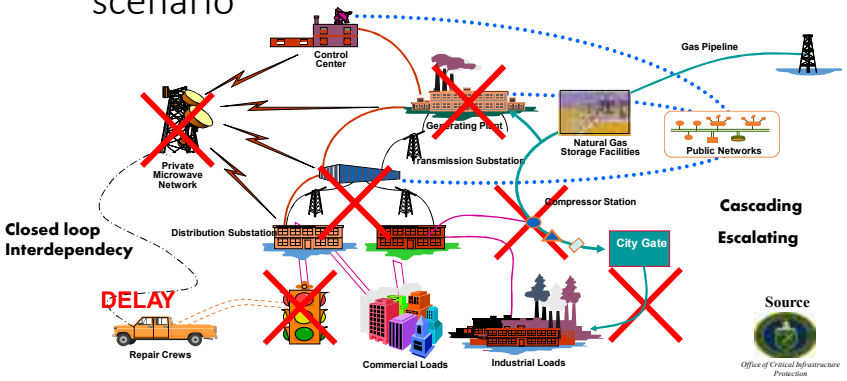


January 2012

S. Rinaldi, J. Peerenboom, and T. Kelly, "Identifying Understanding and Analyzing Critical Infrastructure Interdependencies," *IEEE Control System Magazine*, pp. 11–25, 2001.

M. Ouyang, "Review on modeling and simulation of interdependent critical infrastructure systems." *Reliability engineering & System safety* , pp. 43-60, 2014.

A failure inside an inter-dependent scenario



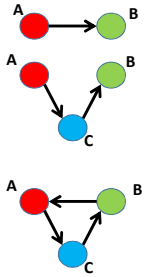
Italian black-out, September 28th, 2003

Due to a «problematic» configuration of the Italian grid, to a problem in Switzerland, to a misunderstanding between Italian and Switzerland TSO operators…

In a rapid sequence the two 400kV lines from France tripped and in 4s GRTN lost the control of the Italian grid

56 million people were affected for up to 9 hours

First and higher order dependency



- First order dependency **A -> B**
- Second order dependency **A -> C -> B**

The concept can be easily generalized to the **n-th order dependency**

When the sequence of influences creates a **loop**, **A -> C -> B -> A** then ALL the involved infrastructures are inter-dependent. Any event is **exacerbated.**

In the presence of loops, there is no more a **tree** structure (i.e. there is a root and the consequences go only downstairs to) but a **graph** structure (the consequences have no more a preferential direction)

Some events

TNO, CI disruption database containing over 4350 reported CI disruption events including over 1260 dependencies (2009)

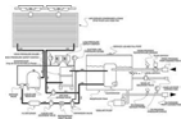
Types of failure

***Common cause**:* the same event produces failure in two or more infrastructures.

***Cascading**:* the failure into one infrastructure induces a domino effect on other infrastructures.

***Escalating**:* the failure of one infrastructure exacerbates the consequences of failure induced by some other causes.

Planned vs. Induced dependency



- **Planned:** the dependency has been introduced at design stage (it is "functional" to the prescribed goal) and it is well known and well documented

- **Induced:** the dependency "*emerges*" due to modification of the environment (generally it is not present/evident in normal operation condition). It is generally not well documented, not perceived by the operators or even unknown

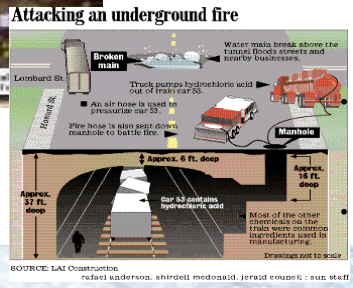
R. Setola, "How to Measure the Degree of Interdependencies among Critical Infrastructures", *Int. J. of System of Systems Engineering, (IJSSE),* pp. 38 -59, 2010.

CSX Tunnel Fire

Lessons identified – Baltimore, July 2001

"unknown" geographical co-location of multiple CI

- Chloride-acid train derailment in tunnel; subsequently went on fire



- 70 million gallons of water flooded downtown streets and houses -> fire fighters lost their water supply.
- Glass fibers melted and caused problem to telephony (local) and Internet (world-wide).
- 1200 buildings lost power

Dimensions for describing infrastructure dependencies

***Physical** Interd.:* if the operations of one infrastructure depend on the physical output(s) of the other.

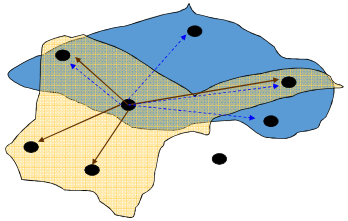
***Cyber** Interd.:* if its state depends on information transmitted via cyberspace.

***Geographical** Interd.:* when elements are in close spatial proximity.

***Logical** Interd.*: any other causes (e.g. regulatory).

***Sociologic** Interd.*: when coupling effects are mediated by (irrational) human behaviors

Several "concepts" of proximity



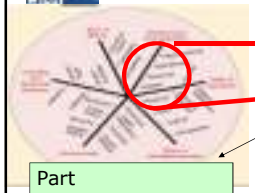
Geographic proximity.
Cyber proximity.

An entity has different sets of neighbors identified on the base of the dependency mechanism.

Hence a given phenomena/failure propagates along common/different pathways.

Consequently specific actions may contrast the propagation of some phenomena (but be ineffective for others).

Infrastructure Characteristics



Spatial	Temporal	Operational	Organizational

- Part
- Unit
- Subsystem
- System
- Infrastructure
- Interd. Infrastr.

Interdependency is more relevant as scope increase

Relevant time scales vary from milliseconds to hours to years

The importance of each type of interdependency changes w.r.t. time horizon

Operational conditions

The dependency degree is influenced largely by the operational conditions:

- **Normal**
- **Stressed**
  - Maintenance
- **Crisis**
- **Recovery**

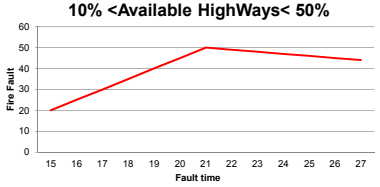
E. Luiijf, and M. Klaver. "Insufficient situational awareness about critical infrastructures by emergency management." TNO Defence, Security and Safety (2011).

Recovery at an oil tank farm

Fire fault mitigation

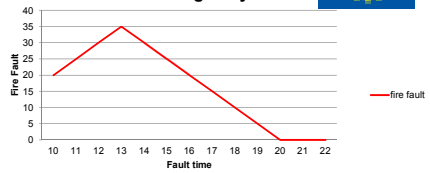
Fire dousing at 13 minutes after the fire start.
Every minute, its value will be reduced of 5%.

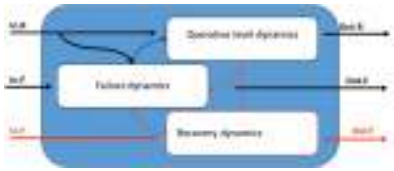
10% <Available HighWays< 50%



Fire dousing at 21 minutes after the fire start.
Every minute, its value will be reduced of 1%.

Available HighWays > 50%





What: Resources and/or Faults

Absence or degraded resource

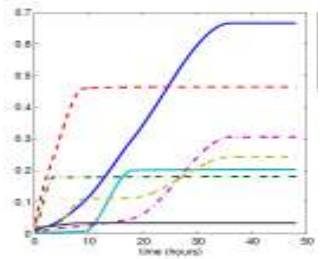
The supplier infrastructure is unable to provide adequate level of resources to the dependent infrastructure.
This later can use its own reserve (e.g. buffer or back-up elements) to reduce the **level of coupling** for a while.
Generally, when the level of resources is restored, the operativeness is rapidly restored.

Fault

The fault (e.g. break, fire, blame, fulmination, etc.) in an infrastructure is transmitted to the dependent infrastructure, where other types of fault can be generated.
The consequences can be mitigated (or nullified) due to the presence and quality of "**barriers**" which effectiveness depends on the amplitude and duration of the fault.
Removing the cause does not imply the restoration of the operativeness.

S. Panzieri and R. Setola, "Failures Propagation in Critical Interdependent Infrastructures", *Int. J. Modelling, Identification and Control* (IJMIC), pp. 69 – 78, 2008.

Time Varying coupling coefficients



Constant: it does not change with outage period, i.e. direct link (no buffer or back up)

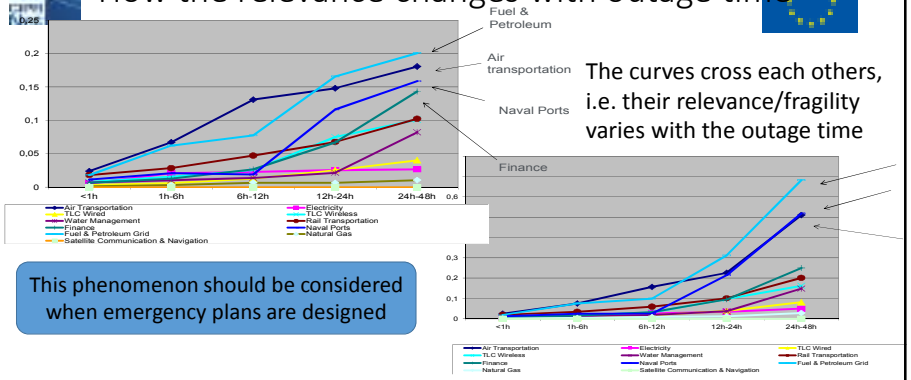
Linear + constant: buffer absorbs partially the inoperability until it expires

S-Shape: buffer absorbs quite completely inoperability for a while but when it expires there is a rapid degradation (no graceful degradation)

Double S-Shape: there are two types of buffers which are designed to support general and priority aspects

F. Conte, G. Oliva and R. Setola, "Time-Varying Input-output Inoperability Model", *Journal of Infrastructure Systems*, ASCE, 47–57 2013.

How the relevance changes with outage time

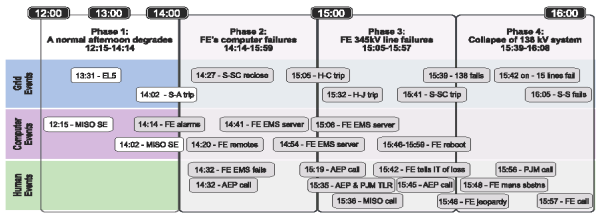


The curves cross each others, i.e. their relevance/fragility varies with the outage time

This phenomenon should be considered when emergency plans are designed

R. Setola, S. De Porcellinis, and M. Sforna "Critical Infrastructure Dependency Assessment Using Input-output Inoperability Model", *Int. J. Critical Infrastructure Protection (IJCIP)*, pp. 170 - 178, 2009.

2003 – US & Canada blackout



August 14th, 2003

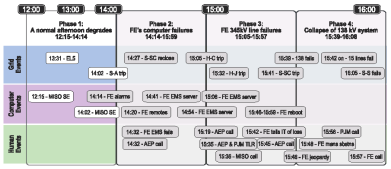
Loss of 61,800 MW of electric load

50 million people affected

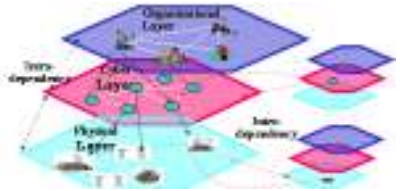
Estimated cost: 4,5 B$ - 8.2 B$

https://reports.energy.gov/

Physical, Logical & Organizational dependencies



To correctly capture the complexity of the phenomena, it is mandatory to have an holistic vision able to aggregate the different visions.



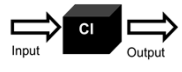
- Physical
- Logical
- Organizational

Each layer is characterized by its own components, resources, faults and links

S. De Porcellinis, S. Panzieri and R. Setola, "Model Critical Infrastructure via a Mixed Holistic-Reductionistic Approach", *Int. J. Critical Infrastructures* (IJCIs), vol. 5, pp. 86 -99, 2009.

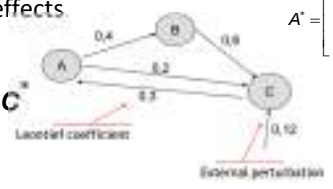
Input-Output Inoperability Model

- Based on the economic equilibrium theory of W. Leontief
- Each infrastructure has an **inoperability** q (% of malfunctioning)
- The model considers constant external perturbations and analyzes the domino effects



$$q(k+1) = A^* q(k) + c^*$$

$$A^* = \begin{bmatrix} 0 & 0 & 0.3 \\ 0.4 & 0 & 0 \\ 0.2 & 0.6 & 0 \end{bmatrix}; c^* = \begin{bmatrix} 0 \\ 0 \\ 0.12 \end{bmatrix}$$



W. Leontief, Input-Output Economics, Oxford University Press, 1966.

Y. Haimes et al., Inoperability input-output model for *interdependent* infrastructure sectors I: Theory and methodology, Journal of Infrastructure Systems, vol. 11(2), pp. 67-79, 2005.

Dependency index & Influence gain

$$\mathbf{A} = \begin{pmatrix} 0 & * & * & * \\ * & 0 & * & * \\ * & * & 0 & * \\ * & * & * & 0 \end{pmatrix}$$

$$\rho_j = \sum_i a_{ij}$$

influence gain

Is a measurement of the influence that a specific infrastructure has on the global system

dependency index

$$\delta_i = \sum_j a_{ij}$$

Is a measurement of the robustness with respect to the transmitted inoperability

Steady-state solution $\bar{\mathbf{x}} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{c} = \mathbf{S}\,\mathbf{c}$

If A is positive and stable, then

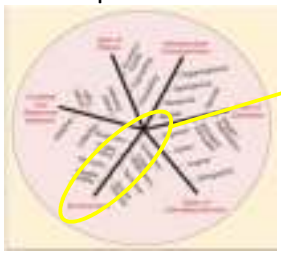
$$\mathbf{S} = [\mathbf{I} - \mathbf{A}]^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \cdots$$

Overall dependency index and influence gain

$$\bar{\rho}_j = \frac{1}{n-1}\sum_{i \neq j} s_{ij} \qquad \bar{\delta}_i = \frac{1}{n-1}\sum_{j \neq i} s_{ij}$$

R. Setola and S. De Porcellinis, "A Methodology to Estimate Input-output Inoperability Model Parameters", *Critical Information Infrastructures Security 2007,* Lecture Notes in Computer Science, Springer-Verlag, Berlin, pp. 149 – 160, 2008.

IIM Operational vs. Economic



Economic (business) links represent just one of the dimension of dependency

Fukushima Nuclear plant

To capture (other) depedencies we have to consider also operational dimension

IIM from Technicians point of view

Identify IIM parameters on the base of operative technicians' expertise (operators' perceptions).

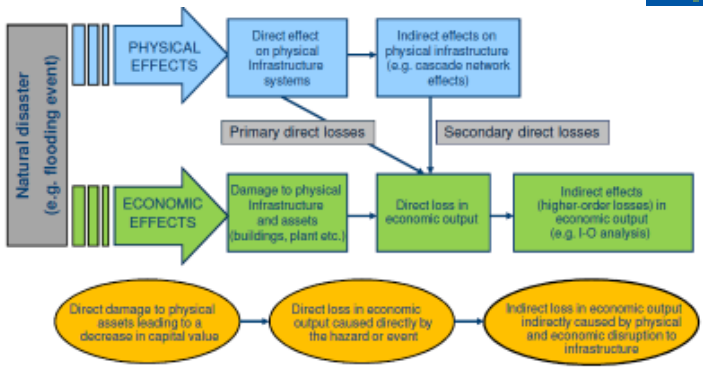
Ask to experts the follow question

Which is the impact of the complete absence of services provided by *yyy* infrastructure for a time period of *zzz* on *your* infrastructure?

In this way we try to acquire directly from their expertise an estimation about the dependency parameters to set-up a technical oriented IIM

R. Setola, S. De Porcellinis, and M. Sforna "Critical Infrastructure Dependency Assessment Using Input-output Inoperability Model", *Int. J. Critical Infrastructure Protection (IJCIP)*, pp. 170 - 178, 2009.

Consequences



S. Kelly, «The cost of cascading failure risk and resilience within UK infrastructure networks", 2014

Recap

- In actual socio-technical scenario all infrastructures are tightly linked each other ➔ negative consequences may increase due to cascading effects and exacerbate in presence of interdependencies
- The mechanisms at the base of dependencies are multiple ➔ this induces several concepts of proximity
- Such phenomena may be more evident in the case of crisis ➔ take into account the effects of dependencies on emergency services

r.setola@unicampus.it

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Topological properties of complex networks and their relevance for CI analysis

Vittorio ROSATO, ENEA Casaccia Research Centre, Roma (Italy)
vittorio.rosato@enea.it

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

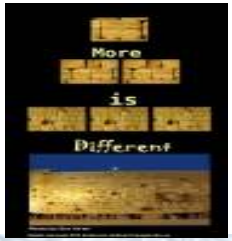
UCBM Headquarters – Rome (Italy) – July 10-11, 2014

Summary

- Complex systems: basic definitions
- Graphs as elementary description for complex systems
- Complex systems properties derived by topological properties of graphs
- Case 1: the Internet
- Case 2: roads, their structure and traffic
- Case 3: electrical networks vulnerability
- Conclusions

Complex systems: basic definitions

- Assume a system of N individuals (living beings, technological objects etc.). Complexity arises when the knowledge of the property of a single element is not sufficient to explain the emerging behaviour of the system of N.



bricks

Western Wall

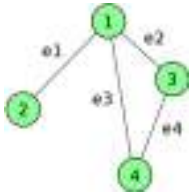
Complex systems: basic definitions

European electrical network

Road networks grow like living objects

Graphs elements and topological properties

- An aggregation of N-bodies could be, at the lowest level of description, represented by a graph where
  - ❑ NODES are the connected elemental entities
  - ❑ LINKS are the physical (or functional) relations connecting them
- Graphs can be DIRECTED or UNDIRECTED
- Graphs can be WEIGHTED or UNWEIGHTED
- The DEGREE of a node is the number of links entering (and/or leaving) from it



Graphs elements and topological properties

- According to the DEGREE distribution, graphs could be classified
- Regular

- Random

- Scale free

Graphs elements and topological properties

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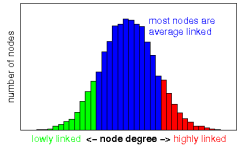
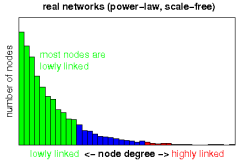
- Regular

- Random



- Scale free



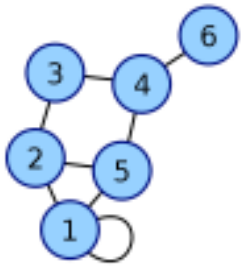
Regular $P(k) = \delta(k_0)$

Random $P(k) = (\lambda^k/k!)\, e^{-\lambda}$

Scale free $P(k) = k^{-\gamma}$

Graphs elements and topological properties

A graph can be fully represented by an **Adjacency matrix a_{ij}**



$$a_{ij} = \begin{pmatrix} 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

Graphs elements and topological properties

-node degree $k_i = \sum_{j=1}^{N} a_{ij}$

-clustering $C = \frac{1}{N}\sum_{i=1}^{N} c_i = \sum_{j,m \in n_i} \frac{a_{ij} a_{jm} a_{mi}}{n_i(n_i-1)/2}$

-betweennees centrality $b_i = \frac{1}{(N-1)(N-2)} \sum_{j,k \in N, j \neq k} \frac{n_{jk}(i)}{n_{jk}}$

- topological efficiency $E[G] = \frac{1}{N(N-1)} \sum_{i,j \in N, i \neq j} \frac{1}{d_{ij}}$

-information centrality $I_i = \frac{E[G] - E[G_i]}{E[G]}$

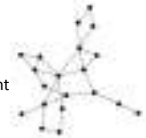
Graphs elements and topological properties

R. Albert, A.L. Barabasi, Rev. Mod. Physics **74** (2002) 47

Graphs as elementary description for complex systems

- At a basic level, complex systems can be described by GRAPHS and by some function describing the "dynamical" activities running on them.

+ TCP/IP protocol stack for the information packets management
THE INTERNET



+ molecular interactions
METABOLIC NETWORKS OF LIVING SYSTEMS

+ Ohm and Kirchoff laws
THE ELECTRICAL NETWORK

+ vehicular dynamics
TRAFFIC IN URBAN ROADS

Graphs as elementary description for complex systems

- The good news is that the analysis of simple topological properties of graphs might already provide relevant information on the functional behaviour.
- This happens because these systems have grown spontaneously. Their structures have been progressively optimized to better comply with some property. The similarity of their structure MUST be a key factor.
- Which are the properties which have been optimized by the peculiar structures adopted by these networks?

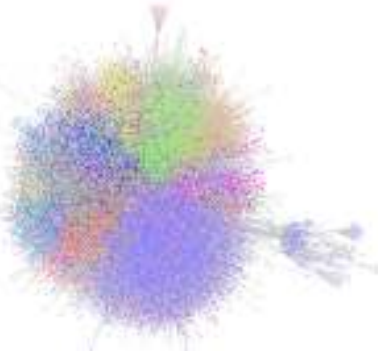
Complex systems properties from topological properties of graphs

- The self-assembly under "complexity" pressure allows systems to structure in a way they reach **robustness AND functionality** .
- **Robustness** means **resilience** to random faults (i.e. the systems could survive to a random perturbation affecting one or more elements).
- To maximize resilience to random faults, networks expose themselves to risks for targeted perturbations

Case 1. The Internet (AS-level routers) as an example of unsupervised growth

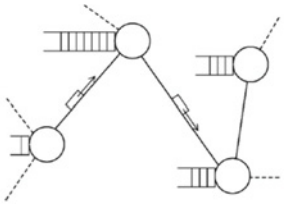
- Pictorial representation of the Internet (AS-level routers network).

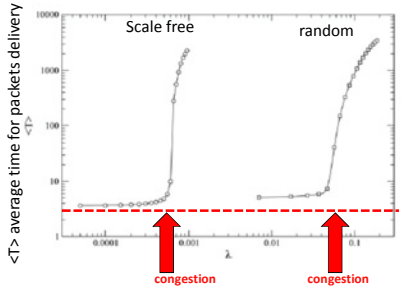
date	N	L	⟨	c	©	MaxD	diam	n_{cut}
1998	3459	6137	1.02 ·10-3	0.194	2.35	734	10	11
1998	4107	7571	8.98 ·10-4	0.221	2.51	855	11	97
1999	4788	8990	7.84 ·10-4	0.237	2.41	1083	11	378
2000	6474	12572	6.00·10-4	0.252	2.46	1458	9	493
2007	17144	46621	3.17·10-4	0.422	2.25	2346	8	1962
2008	23015	74182	2.80 ·10-4	0.446	2.08	3592	8	2083
2011	33673	333437	2.94 ·10-4	0.581	1.97	5904	7	2115



Case 1: the Internet (AS-level routers network)

- Synthetic communication protocol
- Nodes have buffer (size proportional to their k)
- They emit (or absorb) a number of 1kb packets
- Routing is deterministic along shortest paths



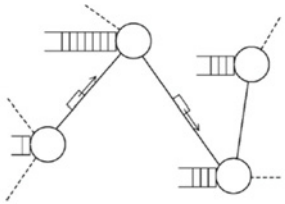


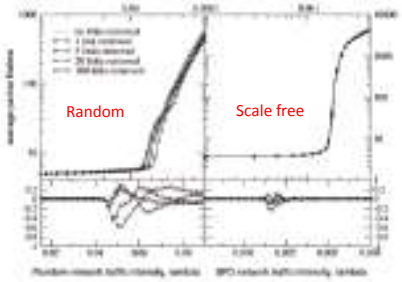
Test 1: test on network topology. Random vs Scale free

- Congestion in random nets appears at higher traffic values !
- **Performance in normal conditions are better for scale free!**

Case 1: the Internet (AS-level routers network)

- Synthetic communication protocol
- Nodes have buffer (size proportional to their k)
- They emit (or absorb) a number of 1kb packets
- Routing is deterministic along shortest paths





Links removal produces perturbations in the communications

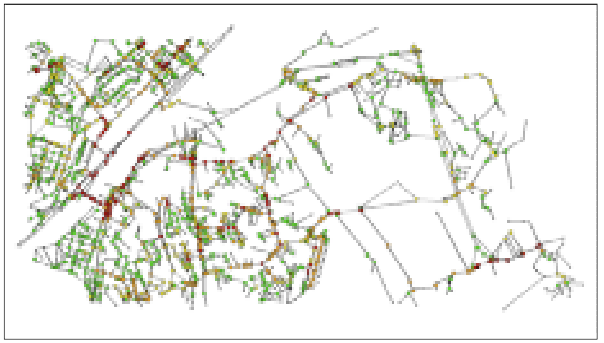
- Random links removal perturbs random network more than scale free

Case 2. Roads, their structure and traffic: a correlation between structure and functions

- Urban displacements determine a huge traffic.
- Local traffic intensity is related to topological properties of urban networks.
- Could we infer traffic information simply by analysing road networks topology ?

Nodes	2650
Links	5445 (523 km)
Directed links	1195 (101km)
Undirected links	2125 (211km)

Case 2: roads, their structure and traffic



Node's Betwenness Centrality: how many times a node is comprised in minimum paths connecting all other nodes

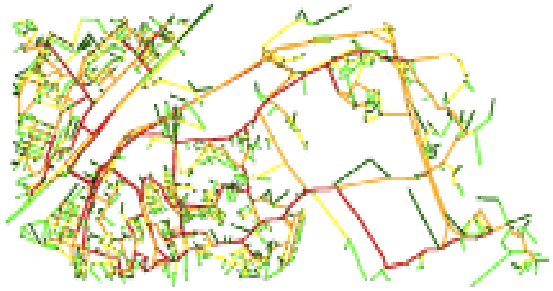
Node's Information Centrality: how a node is relevant in reducing the minimum paths connecting all other nodes

Case 2: roads, their structure and traffic

Growing traffic

Simulation of Nash equilibrium

Traffic leaving and entering in each node



Info on network topology: link's Betwenness Centrality

Case 3. Electrical-telco networks vulnerability

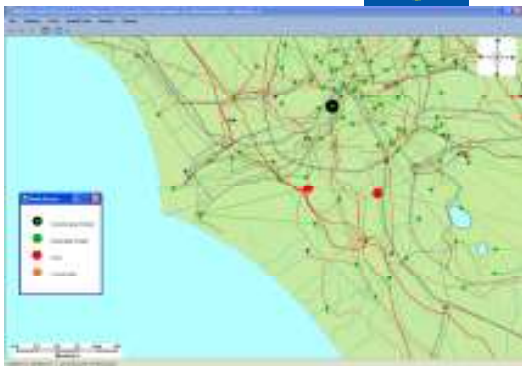
Let us assume to have a Telco network coupled with an HV electrical transmission network (Telco network provides telecontrol operation from control site of the electrical operator).

Green nodes are electrical network telecommunication nodes

Black node is the Electrical Network company management center

Case 3: electrical-telco networks vulnerability

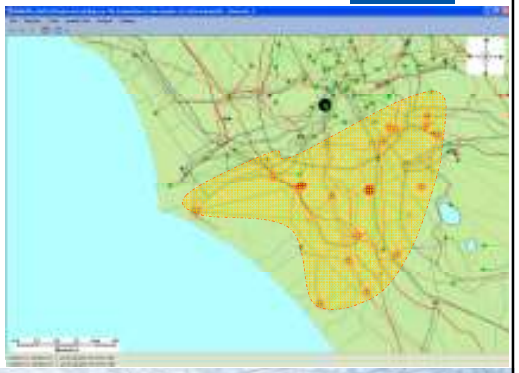
Let us introduce two simultaneous faults (on random positions) on a Telco node (red ones).
One fault (due to network's redundancy, is not sufficient to generate dependency effects.



Case 3: electrical-telco networks vulnerability

As a consequence of those faults, a number of telecontrolling nodes cannot be reached anymore from the control center (orange nodes)

Shaded area cannot be (electrically) controlled upon that fault



Case 3: electrical-telco networks vulnerability

One can play the game of setting in off state all couples (k=2) or triplets (k=3).. out of the ***n*** telco nodes

$$C_{n,k} = \frac{n!}{k!(n-k)!} = \binom{n}{k}$$

and evaluate the Reachability $R(n_i)$ of node n_i by the Central node C^* if a k-uple of nodes are put in off state

Conclusions

- Large technological systems sustain unsu… …wths where they structure themselves to reach a conveni… …between resilience and efficiency in their functio…
- In many cases, correlations between stru… …nction are very strong and networks properties provide … …mation on the network's functioning.
- There is a strong interest, in the last yea… …ese methods for studying dependent and inter-dependent networks on models using graphs and simple dynamical models

http://netonets.org/dup-netonets-2014/)

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How to Save Human Lives with Complexity Science

February 3, 2014

THANKS

vittorio.rosato@enea.it

http://utmea.enea.it/people/rosato/

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Introduction to a Decision Support System (DSS) in the area of emergency management of CI

Vittorio ROSATO, ENEA Casaccia Research Centre, Roma (Italy)
vittorio.rosato@enea.it

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

UCBM Headquarters, Rome (Italy) – July 10-11,2014

Summary

- Decision Support Systems in CI risk management: basic ideas and objectives
- The workflow of a DSS for Risk Analysis and Management
  - Observation and event's predictions
  - Correlation between event's manifestations and damages
  - Impacts from damages
  - Consequences analysis
- Conclusions

Decision Support Systems

- Decision Support Systems (DSS) are a specific class of computerized information system that supports organizational decision-making activities.
- A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or other data sources to identify critical situations and make decisions

• Event's Prediction → Impacts and Consequences estimate →

Risk assessment → Tools for supporting decisions

Decision Support Systems

- Typical information that a decision support application might gather and present would be:
  - Accessing all of your current information assets, including legacy and relational data sources, data from diverse sources, historical data etc.
  - Timeline of predicted events
  - Expected consequences of the predicted events in terms of damages to the CI
  - Expected evaluation of the impacts that predicted damages could have on determining the correct functioning of CI
  - Expected consequences that reduction or loss of relevant services provided by CI could have on population, environment, essential services and industrial sectors

Decision Support Systems

- The DSS designed in CIPRNet aims at to produce a 24/7 assessment of the state of Risk of CI in a given area.

$$R(T,E_k) = P(T)\, V(T, E_k)\, I(E_k)$$

T is a threat manifestation, E_k is a generic element of the k-th CI
$R(T, E_k)$: the Risk associated to the loss of E_k due to threat T
$P(T)$: the probability that the threat manifestation T occurs
$V(T, E_k)$: the specific vulnerability of the element E_k to T
$I(E_k)$: the impact that the system of CI would have in case of lost of E_k

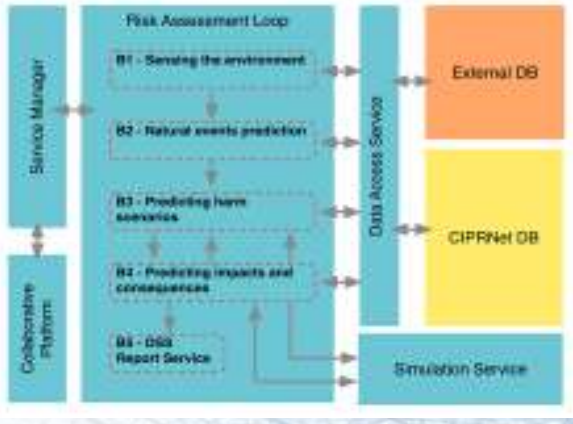
Decision Support Systems

Impacts are meant to be the reduction in the Quality of Services (ΔQoS) experienced by all CI, both the hit CI *k* and the others to which *k* is providing resources.

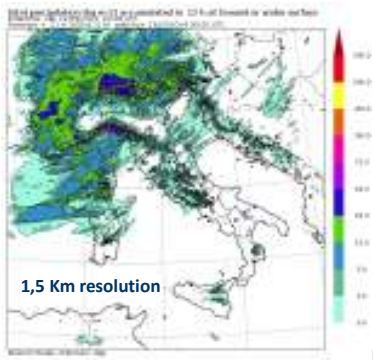
Impacts can be expressed and weighted on the bases of the **consequences** that the reduction of services (ΔQoS) provided by CI can produce on

- Citizens
- Environment
- Services
- Industrial sectors

Decision Support Systems



Decision Support Systems
B1: observation and event prediction



Sensor data
- Seismic network (localisation, magnitude)
- Meteorological satellites network
- Nowcasting radar monitoring network
- Satellite SAR Images

Elaborated data
- Weather forecast
- Climatological forecast (seasonal forecast)
- Nowcasting

Decision Support Systems
B2: observation and event prediction

estations and magnitudes

	2	3	4	5
	0	1	0	0
	1	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0

Decision Support Systems
B3: predicting harm scenario

A Crossing of vulnerability and threats matrices to predict Damage D

A Vulnerability Matrix will be associated to each CI element

$$D = max\{S_{ij} \blacksquare V_{ij}\}$$

Vulnerability Matrix V

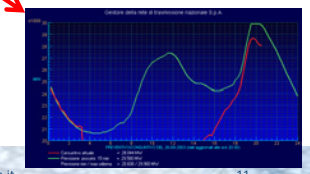
Vulnerability	1	2	3	4	5
Earthquake (ground acceleration)	0	0	0,5	1	1
Strong Wind	0	1	1	1	1
Lightening	0	0	0	1	1
Heavy snowfall	0	0	0	0	1
Ice	0	0	0	0	1
Landslide	0	0	0	0	0
Flash flood	0	0	0	0	0
Flooding	0	0	0	1	1
Mud flows	0	0	0	0	0
Debris avalanches	0	0	0	0	0
Heavy Rain	0	0	0	0	0
Strom surge	0	0	0	0	0
...	0	0	0	0	0

Decision Support Systems
B3: predicting harm scenario

Interacting with CI operators

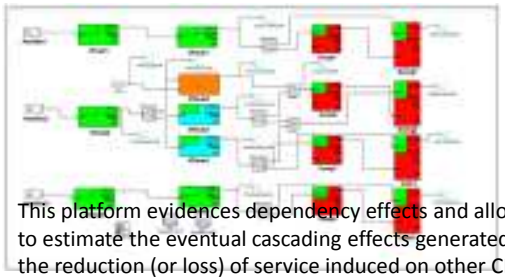
Expected Harm Scenario

Expected Impacts on CI (ΔQoS)



Collaborative Secure Information Sharing Platform

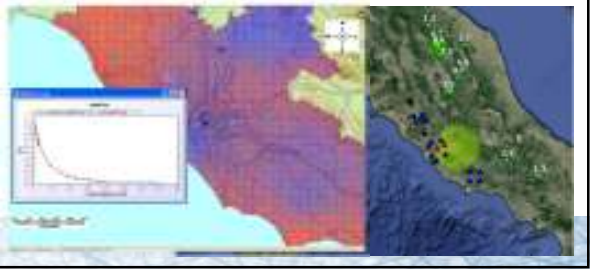
Decision Support Systems
B4: predicting impacts from damages



This platform evidences dependency effects and allows to estimate the eventual cascading effects generated by the reduction (or loss) of service induced on other CI by the wounded one(s).

Decision Support Systems
B4: predicting impacts from damages

At the end of this phase, the DSS will be able to release a "Impact Scenario" which will deliver the course of the expected events in terms of
- Expected perturbation
- Expected damages ("Harm Scenario")
- Expected reduction (or loss) of services ("Impact Scenario")



Decision Support Syste
B4: Consequences analysis a

As a further task, the DSS a
produced by the expected
Sectors:

Sectors	Exa
Citizens	Income, gender,
Industrial	Number of plan plants, number o
Environment	Type of toxic ma type of affected a
Services	Number of hospi

$$C_{sector} = V_{sector} * \Delta QoS = \frac{\partial W_{secto}}{\partial \Delta QoS}$$

Decision Support Systems
B5: Reporting & Decisions

Decision Support Systems
B5: Reporting & Decisions

Decisions could be suggested in some cases:

- Upon analysis of roads and railways availabilities, the DSS could suggest alternative paths to route (or divert) normal traffic and/or emergency patrols
- On the bases of weather forecast, the DSS could anticipate the possible efficiency of energy production from renewable energy sources (photovoltaic by solar illumination, wind for eolic sources, water state for marine energy etc.)
- …. others to be better considered with DSS end-users

Conclusions

- Our idea for increasing system's Resilience is to provide accurate, high resolution predictions of the course of events, starting from hazard's manifestations down to the consequences that predicted CI outages could induce to societal relevant sectors.
- The complex ICT platform set in place could also be used to suggest operators good practices for mitigating impacts on systems and consequences on society.
- The DSS could either be used as an operational (24/7) framework and as an off-line system, for producing specific **stress-test** on the infrastructures.

THANKS

vittorio.rosato@enea.it

http://utmea.enea.it/people/rosato/

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Modelling and Simulation Techniques for Critical Infrastructure Protection

Erich Rome, Andrij Usov – Fraunhofer IAIS (Sankt Augustin, Germany)
{erich.rome|andrij.usov}@iais.fraunhofer.de

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

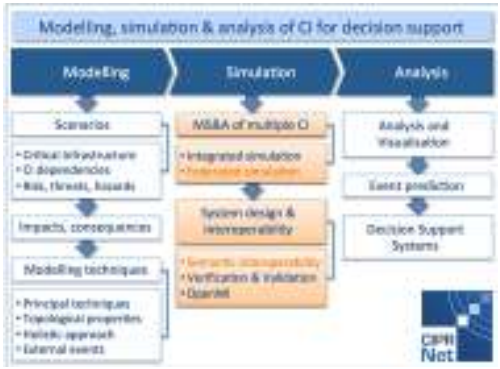
Fraunhofer IAIS

UCBM Headquarters – Rome (Italy) – 10-11 July 2014

Agenda

- **Simulation for CIP**
  - **Application areas**
  - **Challenges**
- **Integrated modelling and simulation**
  - **Basic modelling ideas**
  - **Example: I2Sim framework**
  - **Advantages and disadvantages**
- **Federated modelling and simulation**
  - **Motivation**
  - **Challenges**
  - **Example: DIESIS architectural approach**

Locating the presentation topic



Simulation for CIP

Some applications areas

- **General (offline) CI analysis**
  - Investigating (inter)dependencies between critical infrastructures
    - Implicit, indirect and hidden relations
    - Feedback loops and cascading effects
    - Stability analysis and risk estimation
  - Testing existing and benchmarking new CI control methods
- **Improving preparedness**
  - Soft exercises and real-time training
    - Confrontation with a wide spectrum of emergency situations
- **Operational support**
  - Decision support
    - Extended representation of current situation
    - What-if analysis

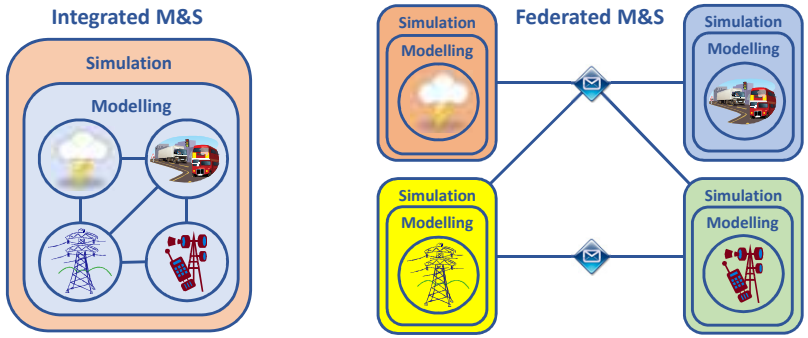
Simulation for CIP

Cross-sector simulation: modelling challenges

- **Heterogeneous CIs**
  - Different modelling principles
  - Different granularity required
  - Different time scales
  - Interdisciplinary expertise needed
- **Data acquisition**
  - Analysis goal has to be defined
  - Concrete CI dependencies have to be identified
  - Data may be sensitive, classified or incomplete
  - Close cooperation with CI operators required

Simulation for CIP

Integrated and federated M&S approaches



Integrated modelling and simulation

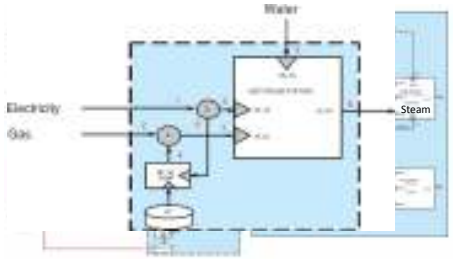
Basic modelling ideas

- Identify the analysis goal
- Find the suitable level of abstraction that:
  - Preserves realistic representation of all analytically relevant properties (qualitative or quantitative)
  - Allows system modelling by means of a generic formalism
- Identify the appropriate modelling formalism
- Create a large homogeneous holistic model
  - V&V: ensure completeness and correctness of the model
- Find existing or implement own simulation and analysis tool

- Simple model: power plant, transmission line, location, working / not working
- Detailed model: power plant, transmission line, transformer, distribution line, substation, location, capacity, nominal and real voltage, production and consumption fluctuations, etc.

Integrated modelling and simulation

I2Sim framework (early version from 2008)



- Formalism: cell-channel model
  - Basic structure: cells and channels
  - Components: controls and function blocks
- Elements: model of a steam station*
- Model: connect cells into one network*
- Solve: I2Sim simulator
- Current version of I2Sim supports federated simulation

*Picture from: Rahman, H. A., et al. I2Sim: a matrix-partition based framework for critical infrastructure interdependencies simulation. In: *Electric Power Conference, 2008. EPEC 2008. IEEE Canada*. IEEE, 2008. p. 1-8.

Integrated modelling and simulation
Advantages and disadvantages

- **Advantages**
  - Proper level of abstraction for a given analysis task
  - As much detail as required but not more than necessary
  - No redundant computations, good simulation performance
  - Does not reveal too much technical details
  - One single simulator can be employed
- **Disadvantages**
  - Models have to be created from scratch (e.g., CI element behaviours)
  - Modelling is very time and resource-consuming
  - Modification of analysis goal and/or scenario: re-modelling is often required
  - Modification of abstraction level for one model part is not possible

Federated simulation
Motivation

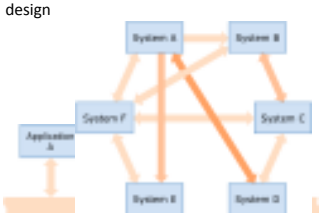
- We can save resources by reusing existing models and interconnect ready-made simulators
- For most domains and CIs, dedicated ready-made commercial and/or free high-fidelity simulators already exist
  - No need for implementation of new tools
- Most CI operators maintain either ready-made correct simulation models of their CIs or detailed inventories of CI elements.
  - Makes resource-consuming modelling and V&V unnecessary
- Requirement: create interaction models that describe interactions between domains and contain only relevant CI elements
- Several approaches exist (often emerged from the military area, e.g., HLA)

Federated simulation
Challenges

- **Semantics**
  - Data integration and conversion
  - Different time models: synchronisation (preservation of causality)
  - It may be necessary to create concepts or elements outside particular domains at federation level
- **Technology**
  - Heterogeneous software: interfacing simulators
  - Different levels of abstraction: avoid redundant computations
  - Orchestration of different execution concepts of federate simulators
  - Communication and event routing among federates

DIESIS architectural approach
Interoperability middleware for federated MS&A

- Designed for heterogeneous interdependent federated CI simulations
  - Federates are not required to support common standards (e.g., HLA)
  - Federates have different time models and different time scales
  - Methodology for arbitrary scenarios, scenario-oriented federation design
  - Flexible modelling, extensibility of federations
  - Service-oriented scenario design
- DIESIS interoperability middleware is based on two concepts
  - Separation of technical and semantic interoperability
  - Lateral (instead of central) coupling of federates



DIESIS architectural approach

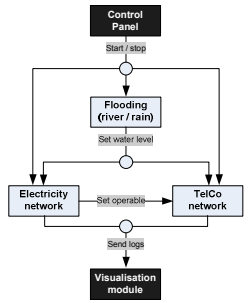
Interoperability layers

- **Semantic interoperability**
  - DIESIS Knowledge Base System: a general modelling framework
  - CI elements/properties that are involved in cross-domain interactions
  - Federation level concepts: static dependency representation (relations), dynamic dependency concepts (behaviour)
- **Technical interoperability**
  - Reusable simulator coupling links, dedicated types:
    - Time links: ensure correct event ordering
    - Data links: exchange state changes (events)
    - Function links: mutual function calls
    - Control links: manage runtime behaviour

DIESIS architectural approach

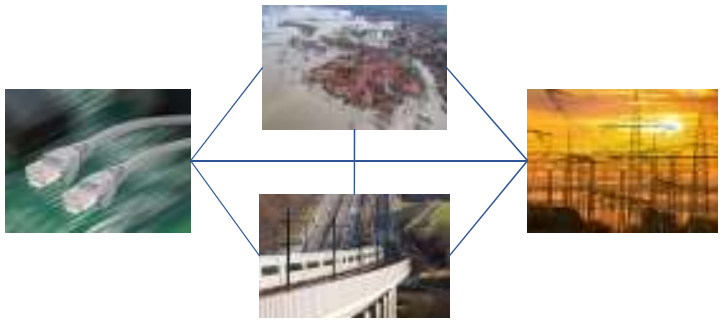
Scenario-oriented design: conceptual phase

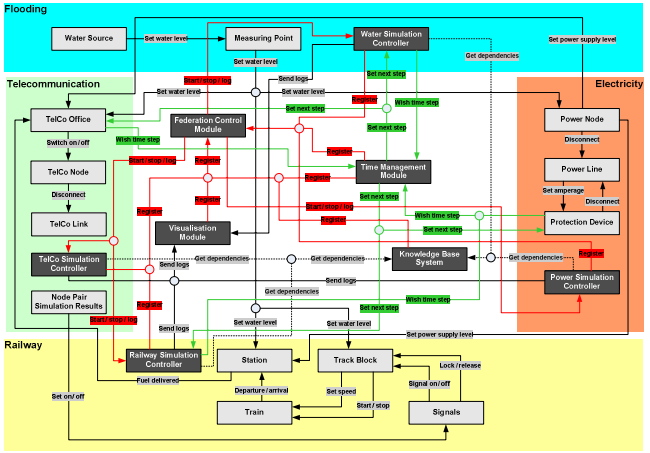
- Enunciate general requirements and the goal
  - Which domains are involved and how do they interact?
  - What do we want to investigate?
- Provide an informal, human-readable, computation-independent model
  - Capture all elements related to cross-CI interactions, no insight into CI-specific structure and behaviour required!
  - Identify agent types and services, construct a service network
  - Describe both abstract and technical elements



DIESIS architectural approach

DIESIS demonstrator



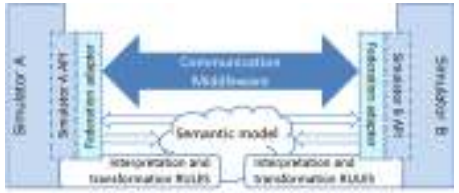


DIESIS architectural approach
Scenario-oriented design: modelling phase

- Provide a formal, machine-readable representation of the informal model
  - Conceptual level: add all concepts for domain element types and their relations
  - Instance level: instantiate domain element types, add concrete elements and relations
  - Dynamic level: provide description of service behaviour
  - A *power station* provides energy for a *TelCo building*.
  - *TelCo building* **TB12** receives power from the *power stations* **P20m** and **P18m**.
  - Any kind of equipment inside a *TelCo building* is **off** if none of the *power stations* linked to it has a property **VoltageLevel** over 80% and the own *backup power supply unit* is discharged.

DIESIS architectural approach
Scenario-oriented design: implementation phase

- Implement all technological components (see service network)
- Implement communication layer or add interfaces to existing RTIs
- Implement federation adapters for all simulators
- Remove bottlenecks, optimise performance
- Validate simulation results



DIESIS architectural approach
Features and advantages

- Structuring of modelling and development in order to facilitate the process and to minimise efforts
- Modelling at federation level concerns only those elements that are relevant for dependency definition
- No deep insight into structure and behaviour of all (scenario-relevant) domains is required for modelling
- Flexibility: depending on desired results, particular simulators and models can be added, removed or replaced
- Reusability: technical components, models and concepts and can be utilised for various scenarios

M&S methodologies for CIP
Conclusion

- Modelling and simulation are very useful for many applications related to CIP
- Analysis of multi-CI systems is challenging
- Integrated M&S approach
  - Uniform modelling: single simulator required
  - Good performance: important for real-time applications
  - Limited flexibility in relation to realisation of new scenarios
- Federated M&S approach:
  - Reuse existing simulators and models: reduce realisation costs
  - Best flexibility for changing scenarios and different analysis tasks
  - Interoperability: currently no established standards for CIP but several approaches exist

Thank you for your attention!

Any questions?

Fraunhofer
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CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Introduction to OpenMI

Bernhard Becker and Annette Zijderveld - Deltares
bernhard.becker@deltares.nl, annette.zijderveld@deltares.nl

Deltares

Modelling, Simulation and Analysis of Critical Infrastructures
Master Class (Edition1)

Rome (Italy) – 10-11 July 2014

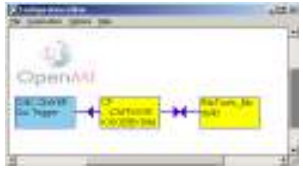
Contents

-What is OpenMI?
-Example application cases
  - coupling of water related models
-Introduction to the life demonstration
-OpenMI life demonstration
-OpenMI compliance requirements

What is OpenMI?

OpenMI is an open model interface standard for hydro-related models developed by the OpenMI Association

- Designed for water-related models
- For legacy code and new code
- Data-exchange during runtime per time step
- Open source

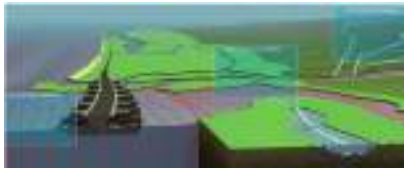


Example: RTC-Tools and Sobek in the OpenMI configuration editor

- Used already by several institutions (Deltares, DHI, BAW, RWTH Aachen University, Université de Liège, US Geological Survey, ...)

What is a model?

Conceptual model: How does a system operate?
Mathematical model: A set of equations
deterministic (physics-based) – empirical – logical
Computer model: Coded equations
Generic model: Simulation software (GUI, input, output)
Site-specific model: Generic model + site-specific data



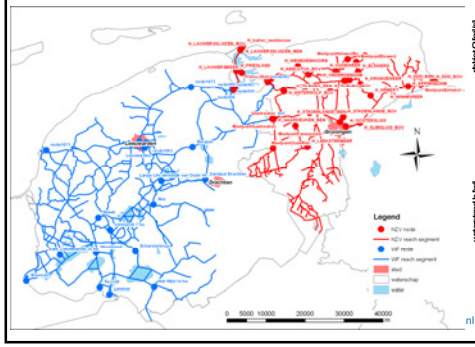
When to apply OpenMI?

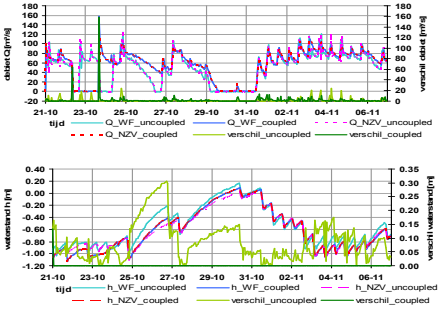
Coupling of models of different processes
- one model for each process
- both processes are of similar relevance
- processes on different time scales

Coupling of models of the same type
- models belong to different institutions
- models are used coupled and uncoupled (maintenance, calibration, local studies)

Coupling two channel flow models

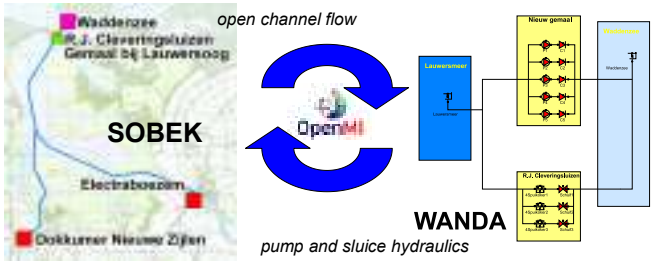
Channel flow models Wetterskip Fryslân and Noorderzijlvest coupled at three connection points
One water system, two water authorities



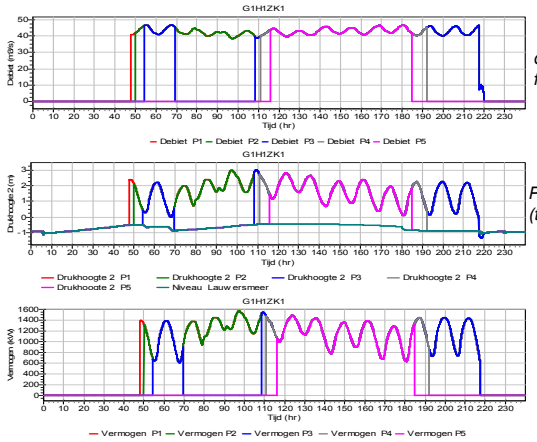


Channel flow ←→ industrial hydraulics

Design of a pump station for lake Lauwersmeer (the Netherlands)
more extreme rainfall events and rising sea level expected
drainage of polder areas must be facilitated with a pump station



Channel flow ←→ industrial hydraulics

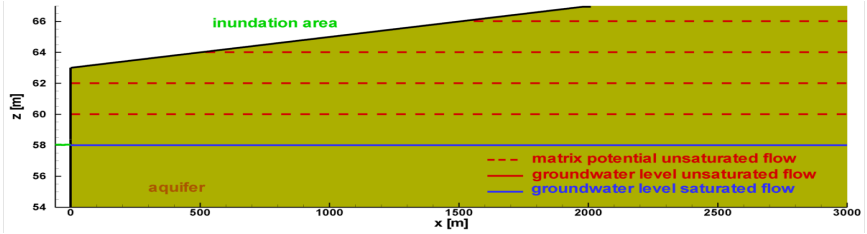


discharge from WANDA for SOBEK

Pressure head from SOBEK (tidal influenced)

power consumption from WANDA for design

Surface water flow ←→ groundwater flow



Simulation period: 14 days

Two coupled simulations:

Surface water		Groundwater
Ilmoflood	←→	Feflow saturated
Ilmoflood	←→	Feflow unsaturated

coupling:

Ilmoflood		Feflow
head	→	leakage
flow	←	flow

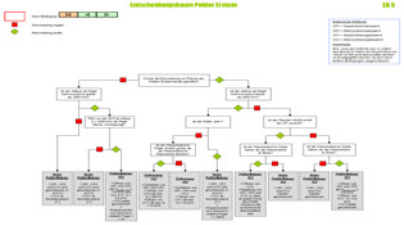
Channel flow ←→ human operations

Control of the Oberrhein (upper Rhine) water system:

Decision tree and open channel system

SOBEK: open channel flow

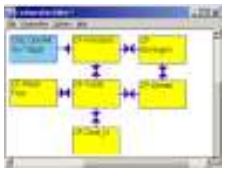
RTC-Tools: human operations (control)



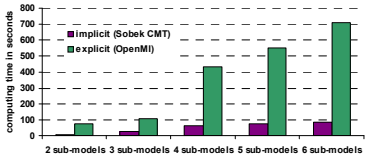
Sobek		RTC-Tools
Channel flow (Q, h)	→	**Water system state**
Control parameter	←	**Control parameter (crest level, turbine discharge)**

Dutch Large Scale SOBEK model

- From 2 to 6 model coupled:



Dutch Large Scale SOBEK model



- Water level differences: less than 3 cm
- Discharge differences: less than 1 m^3/s
- Computational effort of explicit coupling increases disproportionally with the number of sub-models

→ implementation of OpenMI standard into Sobek has high potential to increase performance

What is conjunctive modelling?

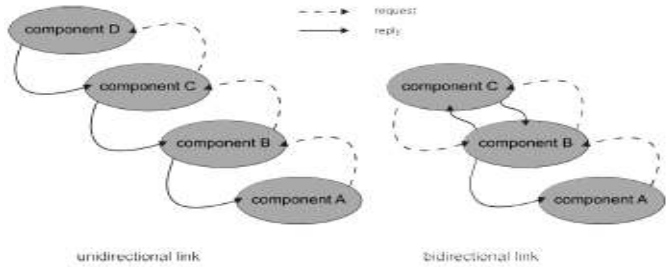
Conjunctive modeling:

- link models to model process interaction

Coupled modeling:
- data transfer in two directions.
- requires data exchange on a time step basis

Uncoupled conjunctive modeling:
- data transfer in one direction
- not necessarily o n a time step basis.

Unidirectional and bidirectional coupling



uncoupled coupled

Different Types of Coupling

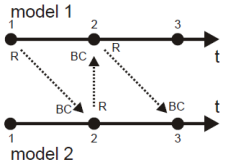
Simultaneous coupling: the highest level of model coupling
- different processes, including their interactions, are represented in one equation system

Iterative coupling
- exchange data between models during runtime in two directions and iterate the exchange of data until a certain convergence criterion is achieved

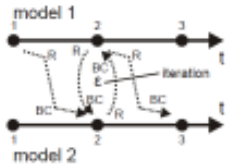
External coupling
- data exchange per time step, successively, but without iterations.

OpenMI supports iterative coupling and external coupling.
→ OpenMI is a standard for federated modeling
(see presentations by A. Usov and W. Huiskamp)

Model coupling



External coupling
- easy to implement
- mass balance errors



Iterative coupling
- advanced
- more accurate
- computationally more expensive

Simultaneous solution: multiple processes in one equation system
- highest level of coupling
- accurate
- time steps resolution must be the same
- equations must be of the same type

Hands on!

Objective: design a model chain for the following scenario:

1. Heavy rainfall causes high water in a river.
2. High water in a river causes dike breach due to overtopping.
3. The dike breach causes inundations of the hinterland.
4. From the inundated areas water infilltrates into the subsurface and causes groundwater head rise.
5. Rising groundwater levels create uplift forces on a road tunnel and flows cellars with information technology installation.

Tasks

1. Identify the relevant processes and the corresponding models.
2. Draw a sketch of models and their interactions.
3. Discuss the benefit of model coupling.
4. Discuss alternative set-ups.

Solution task 1: processes and models

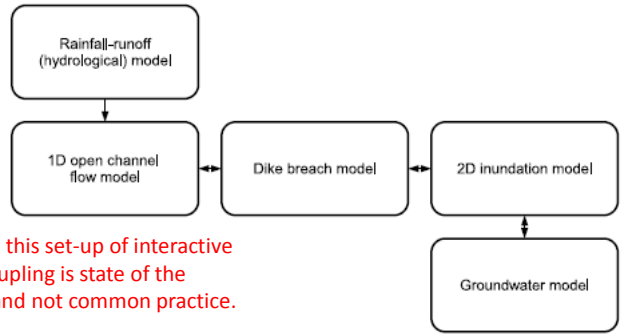
No.	Process	Model
1	Rainfall-runoff	Hydrological model
2	River flow	1D open channel flow model
3	Dike breach	Dike breach model
4	Hinterland flooding	2D inundation model
5	Groundwater head rise	Groundwater model

http://en.wikipedia.org/wiki/File:Surface_water_cycle.svg

www.tu-dresden.de

www.benno-gym.de/Sites/About/Archives/Flood/

Solution task 2: models and their interactions



Note that this set-up of interactive model coupling is state of the science, and not common practice.

Solution task 3: benefits of model coupling

Feeding the rainfall-runo model with a rainfall scenario produces results without manual data transfer between the models.

River flow, dike breach and inundation are processes that interact with each other. Uncoupled modelling would violate the mass balance of water.

The infiltration of water from inundated areas into groundwater is an interaction process which cannot be modelled uncoupled.

The model chain provides information that can be used to identify endangered critical infrastructure.

Solution task 4: alternative set-up

A connection between the river model and the groundwater model adds bank interaction to the system model.

Interactions between river model, dike breach model and two-dimensional flow model could be made uni-directional to trade-off accuracy against performance.

A geotechnical model for failure mechanisms due to uplift forces can be added to the modelling chain.

Show case

Flood events can have major impact on CI

- End of May 2013 a V*b* meteorological situation occurred over central Europe
  - highly saturated soils in Austria and Germany
  - About 400mm rainfall within 4 days
- Highest water levels on river gauges along Elbe, Danube and their tributaries expected (and observed)
- Several impacts on CI such as
  - Damages on a highspeed railway bridge at the Elbe (breakdown > 5 month)
  - Flooding of major highways along the Danube River (breakdown > 4 weeks)
  - Potential flooding of a power distribution station (breakdown >> 12 month)

Elbe 2013 around Magdeburg

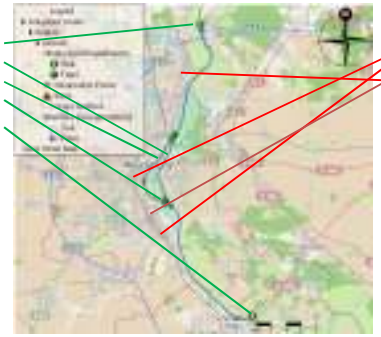
Reference (both figures): wikipedia.org

Demo: Elbe river, Magdeburg (Germany)

Study area with Sobek model schematization

Hydraulic objects
- Gauges "Magdeburg"
- Old Elbe branch
- Main river channel
- Weir
- Gauge "Schönebeck"

Critical infrastructure
- Railway track junctions
- Main railway station
- Power Substation



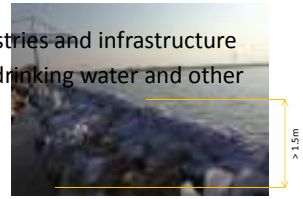
Elbe 2013 around Magdeburg

Power Distribution Station *Rothensee*

- 110kV network for local power distribution
- responsible for about 30,000 households, industries and infrastructure
- Urgently required for pumping of flood water, drinking water and other vital services
- Cascading effects of cut-off not known

Located along the Elbe River

- Significantly lower than the flood water level
- Temporarily secured by a sand bag barrier



obtained from dlrg.de

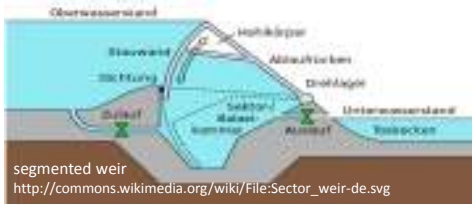
Elbe 2013 around Magdeburg

remote sensing data provided from perils.org

obtained from N24.de (top) and mdr.de (bottom)

Modelling question

Control the weir in such a way that the water level in the main river remains below the flood warning level (54.75 m).



Approach: Coupled model for open channel flow and real-time control.

The open channel flow model

Study area with Sobek model schematization
physical model (St.-Venant equations)

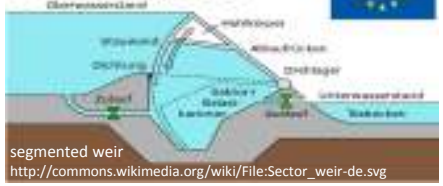
Hydraulic objects
- Gauges "Magdeburg"
- Old Elbe branch
- Main river channel
- Weir
- Gauge "Schönebeck"

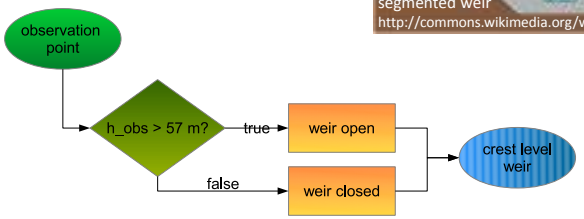
Observation point
Warning level
Control point

Sobek
open channel flow model

The real-time control model

RTC-Tools
real-time control model





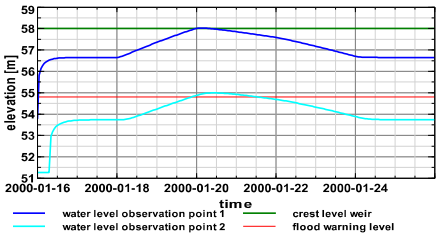
logical/relational model

Processes and models

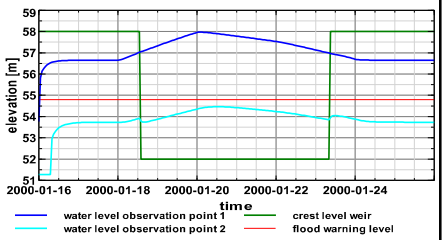
	Open channel flow	Human operations (control of hydraulic structures)
Simulation programme	Sobek	RTC-Tools
Output parameters	Water level, discharge	Crest level
Input parameters	Crest level	Water level

Simulation results

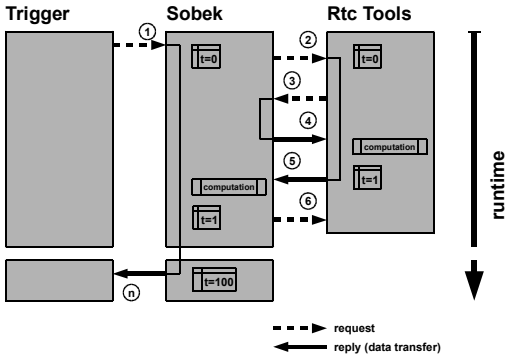
Sobek



Sobek and RTC-Tools



Data exchange mechanism



2: crest level?
3: water level?
4: water level!
5: crest level!
6: crest level?

Setting up an OpenMI-Composition

omi-file: the OpenMI-Compliant Component

- Where is the DLL with the computational core and OpenMI-Interface?
- Where are the input files?
- What else? (Command line arguments)

opr-file: the OpenMI-Composition

- Which components (i. e. models)?
- How coupled?
- Which simulation period?
- Where is the Trigger linked with?

OpenMI Exchange items

What?
- water level in metres
- discharge in m³/s
- crest level in metres

Where?
- Gauge Schönebeck
- Weir 1

input exchange items:
- boundary conditions
- control states

output exchange items
- simulation results

OpenMI-compliance

DLL with OpenMI-functions

- `Initialize()`
  - read input files
  - populate exchange items (e.g. water level in meters at node number 62)
- `GetCurrentTime()`
  - returns the current simulation time as Modified Julian Day
- `GetValues()`
  - returns a simulation result for an Output Exchange Item
- `SetValues()`
  - sets a value for an Input Exchange Item (boundary condition)
- `PerformTimestep()`
  - solves the flow equation for **one** time step

Migration to OpenMI compliance

Re-organise the computational core

- `.exe` → `.exe` and `.dll`
- break the big loop over all time steps (t < tend)
- provide internal functions ("native layer")
  - `ComputeOneTimeStep()`
  - `ReturnListOfNodes()`
  - `ReturnSimulationTimeInSeconds()`

Couple the computational core (engine) with the OpenMI source code (C#) via MSDN PlatformInvoke

Fill the OpenMI `ILinkableEngine` member functions

Who should apply OpenMI?

"The long term aim is that the OpenMI should become the European and global standard for model linking in the environmental domain." (from the OpenMI-life website)

Researchers that develop source code for their studies

- research code can be coupled with OpenMI compliant models

Developers of integrated (hydrological) modelling tools

- coupling of surface/subsurface flood models

Consultants that need dedicated model coupling

- flexible, standardized coupling technique
- use the OpenMI standard for more than one coupling task

Multidisciplinary studies

- CIPRNet - coupling of CI models

OpenMI history

HarmonIT - OpenMI v1.0

- OpenMI was developed by 14 organizations from 7 countries in the EU-project HarmonIT in order to facilitate the simulation of interacting processes, particularly environmental processes
- the first version has been released as the OpenMI Standard v1.0 (.Net version)

OpenMI-Life - OpenMI v1.4

- Further development has been performed in the OpenMI-Life project with a consortium of 10 partners from 5 countries
- release of v1.4 (.Net, Java), foundation of the OpenMI Association

Released - OpenMI v2.0

- Several new features are introduced, including a more flexible way of linking, more flexibility in the overall control flow, less difference between temporal and spatial models
- A new user interface (GUI) and a software development kit (SDK) allow users to make their models 2.0 compliant

Outlook

High potential for coupled flow simulation across

- country borders (e.g. Germany, The Netherlands)
- institution borders (two neighboured water authorities)
- software producer borders (Deltares-DHI, Deltares-Alterra)

For coupled processes model coupling is already frequently applied:

- DeltaShell, Sobek 2, OpenStreams …
- OpenMI-coupling can be a first step for more: RTC-Tools is now integrated in DeltaShell

Next steps:

- Bring the OpenMI technique to consultants, universities and other disciplines
- Get further on-the-job-experience with OpenMI 2.0
- OpenMI - CIPRNet workshop during the Delft Software Days on 27th October 2014

Take home messages

Coupling of models allows to simulate interaction processes

OpenMI offers the possibility to couple models in different ways

Results and computation time depend on the coupling properties

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Federated Simulations

Edwin van Veldhoven - TNO
edwin.vanveldhoven@tno.nl

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

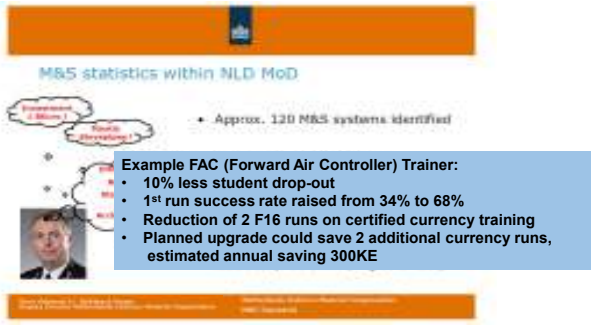
UCBM Headquarters – Rome (Italy) – 10-11 July 2014

TNO

Content

- M&S in support of capability lifecycle
- Federated simulations
- Interoperability standards
- HLA
- DSEEP process
- Summary

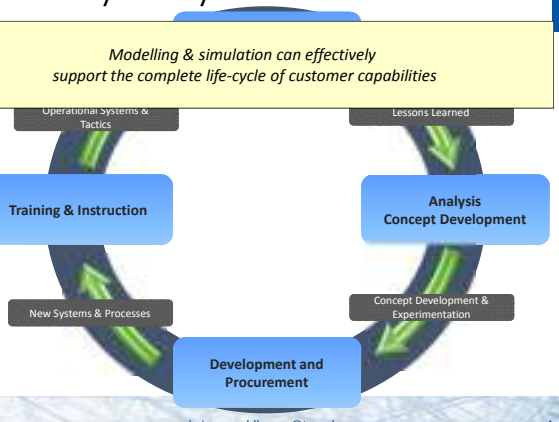
Increasing importance of simulation



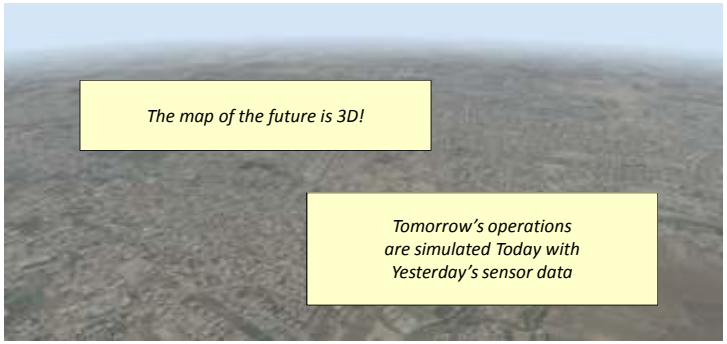
Example FAC (Forward Air Controller) Trainer:
- **10% less student drop-out**
- **1st run success rate raised from 34% to 68%**
- **Reduction of 2 F16 runs on certified currency training**
- **Planned upgrade could save 2 additional currency runs, estimated annual saving 300KE**

Capability lifecycle

Modelling & simulation can effectively support the complete life-cycle of customer capabilities

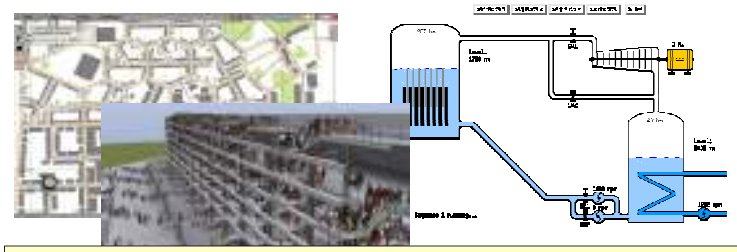


Synthetic environment modelling



Synthetic environment modelling

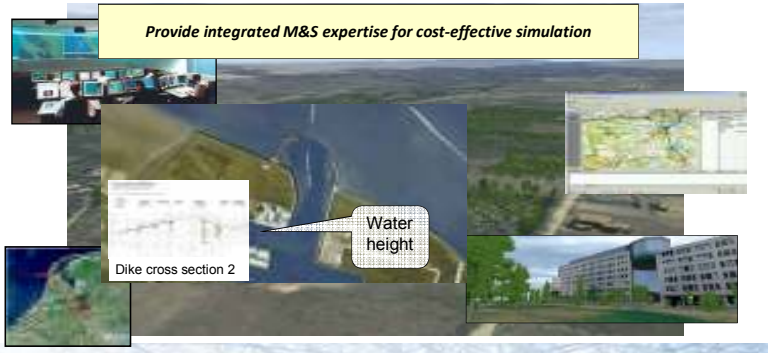
System and behaviour modelling



Create realistic and rich scenarios with minimal expert resources

'From days to hours'

Simulation systems engineering



Statements based on experience

- No single simulation can solve all your problems
- Monolithic simulations are hard to re-use:
  size does matter, smaller is better
- Interoperable components of suitable granularity provide maximum flexibility

Terminology

- **Federation**: a set of simulations, a common federation object model, that are used together to form a larger model or simulation
- **Federate**: a member of a federation; one simulation
  - Could represent one platform, like a cockpit simulator
  - Could represent an aggregate, like an entire national simulation of air traffic flow
- **Federation Execution**: a session of a federation executing together

Federated simulation versus monolithic simulation

- Available training systems are re-used
  - Local training remains possible
  - Specialist tools leveraged
  - Travel savings
- Flexible combinations possible
  - Individual training needs
  - Team training (security levels)
  - Maintenance and incremental upgrades

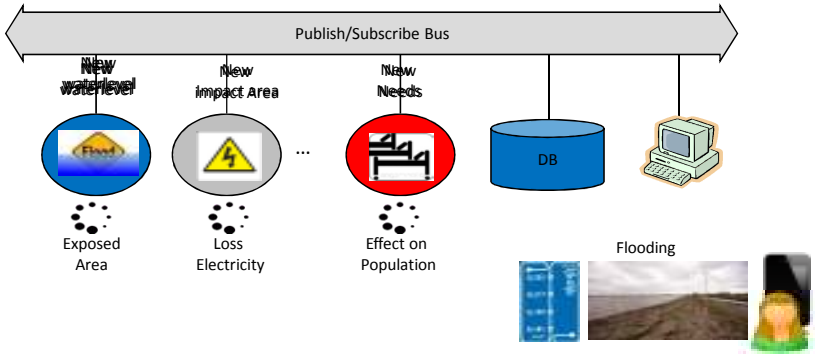
Federated simulation components

- **Man-in-the-loop simulators**
  - Aircraft, vehicles
  - Human players
  - Systems, Command & Control (C2) stations
- **Computer Generated Forces (CGFs)**
  - Vehicles, individuals, systems
  - Environmental effects (e.g. weather)
- **Exercise management facilities**
  - Scenario development tools
  - Briefing/debriefing tools
- **Analysis and assessment tools**
  - Loggers
  - 3D viewers
- **Network infrastructure**
  - Local
  - Wide area
  - Security/encryption

CIP federation example (1)

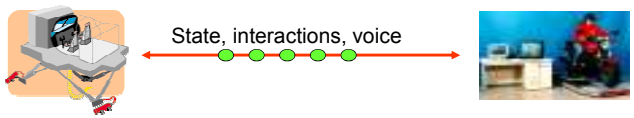
- Flooding impact

CIP federation example (2)

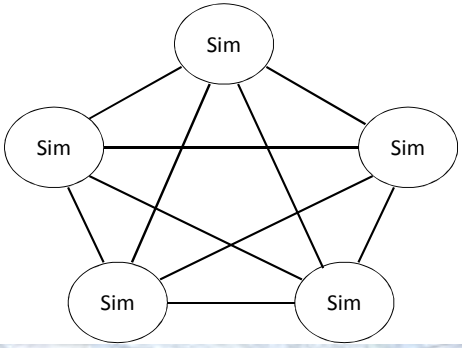


Interoperability

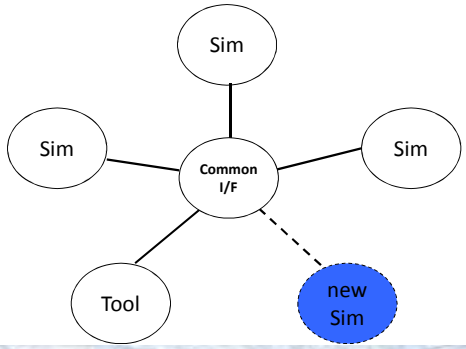
- Definition: the ability of simulations to provide services to and accept services from each other



Interoperability of simulation assets



Interoperability of simulation assets



The interoperability challenge

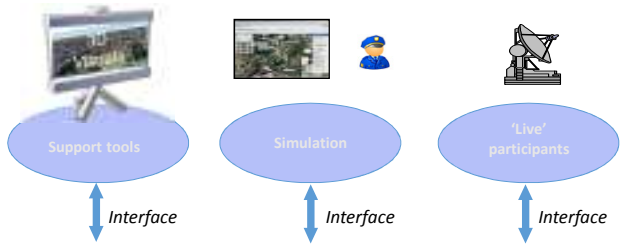
- Bits & bytes vs. meaning:
  - '23': 23 what? ft. altitude, bottles of beer?
  - 'You are dead': 'No way, You've missed me'
  - 'You are 50% dead': 'So what, I can still fight'
  - 'I can see you, but you can't see me'
- Challenges:
  - Standards and versions (HLA, DIS, …)
  - Vendor implementations & compliancy

Modelling & simulation standards

- Advantages:
  - Economy of scale
  - Comply with legislation
  - Promote interoperability
  - Promote common understanding
  - Introduce innovations, transfer research results
  - Encourage competition
  - Facilitate trade
- Challenges:
  - Consensus
  - 'Not Invented Here' syndrome
  - Vendor lock-in
  - Maintenance

Modelling & simulation standards

High Level Architecture (HLA)



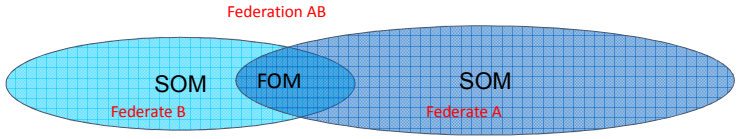
IEEE 1516-2010

High Level Architecture (HLA)

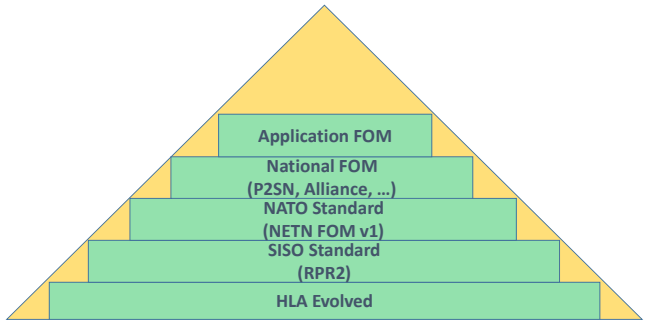
- HLA rules:
  - Must be observed by federates
  - 5 requirements for federations
  - 5 requirements for particular federates
- Runtime Interface (RTI):
  - Defines functional interfaces (service) between federates and the RTI
  - RTI is software, it is not a part of specification
- Object Model Template (OMT):
  - Specification of all objects and interactions
  - Federation Object Model (FOM)
  - Simulation Object model (SOM)
  - Management Object model (MOM)

Object models

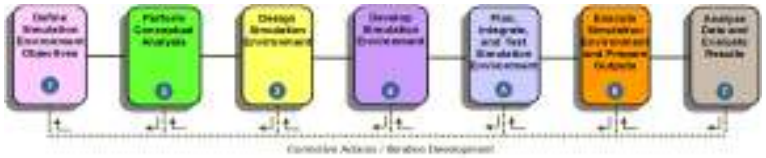
- Federation Object Model (FOM):
  - A description of all shared information (objects, attributes, and interactions) essential to a particular federation
- Simulation Object Model (SOM):
  - Describes objects, attributes and interactions in a particular simulation which can be used externally in a federation



FOM: technical baseline



Distributed Simulation Engineering and Execution Process (DSEEP)



- IEEE 1730-2010: a seven step **engineering process model** for the development and execution of a distributed simulation environment
- Each step is broken down in activities and tasks, with activity inputs and potential outcomes
- Generally applicable, evolving further by input from the user community

1. Define simulation environment objectives

*Define and document a set of **needs** to be addressed through the development and execution of a simulation environment and transform these needs into **objectives** for that environment.*

A

- ssion area
- jectives
- ctiveness/Pe

System Of Interest: Command and Control processes between actual ship, with actual operators and systems

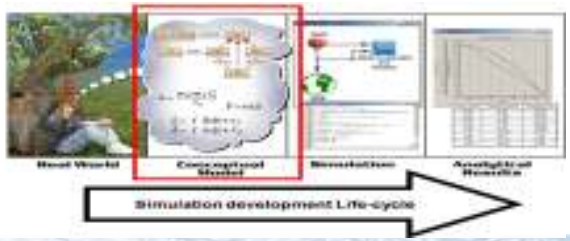
Objective: quantify and evaluate proposed improvements to support acquisition decisions, using Monte Carlo simulation for analysis

MOEs: Time to identify and classify real world objects, …

Start with **Use Case Model** to show real world activities

2. Perform conceptual analysis

*Develop **representation of the real-world domain** that applies to the defined problem space, develop the **scenario**, and transform objectives for simulation environment to **requirements**.*



3. Design simulation environment

*Produce the design of the simulation environment. This involves identifying **member applications**, creating new member applications, allocating **required functionality** to member applications, and developing **planning documents**.*

Activities include:

- Member application selection and trade-off analysis
- Allocation of responsibility to represent entities and actions in the conceptual model to member applications

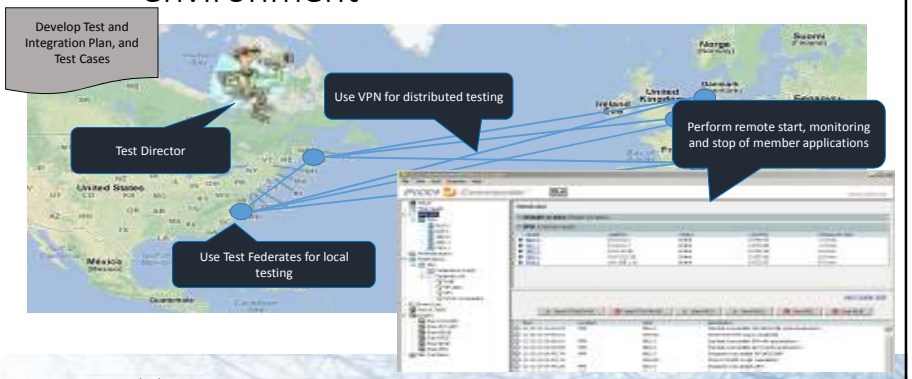
4. Develop simulation environment

*Define the **information that will be exchanged** at runtime during the execution of the simulation environment, **modify member applications** if necessary, and prepare the simulation environment for integration and test.*

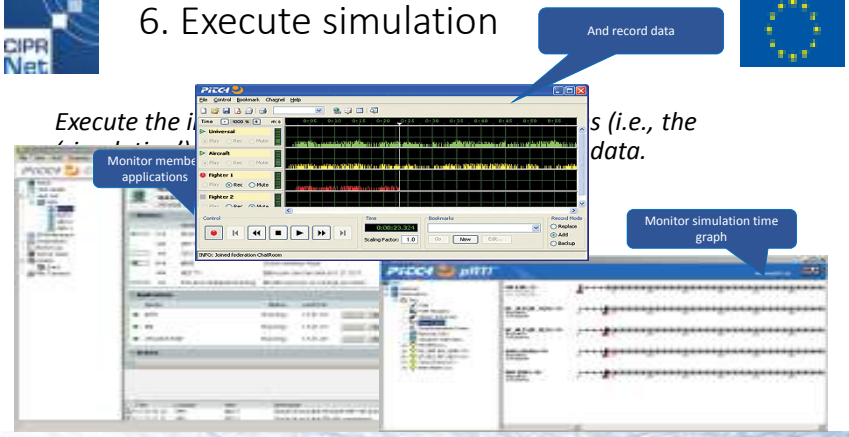
Activities include:

- Develop simulation data exchange model
- Establish simulation environment agreements:
  - initialization, synchronization, termination, progression of time, events, life cycle of entities, update rates, time and space units, dead reckoning, entity ownership, …

5. Integrate and test simulation environment



6. Execute simulation



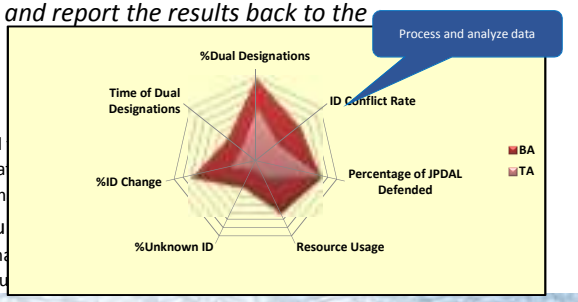
Execute the i… s (i.e., the … data.

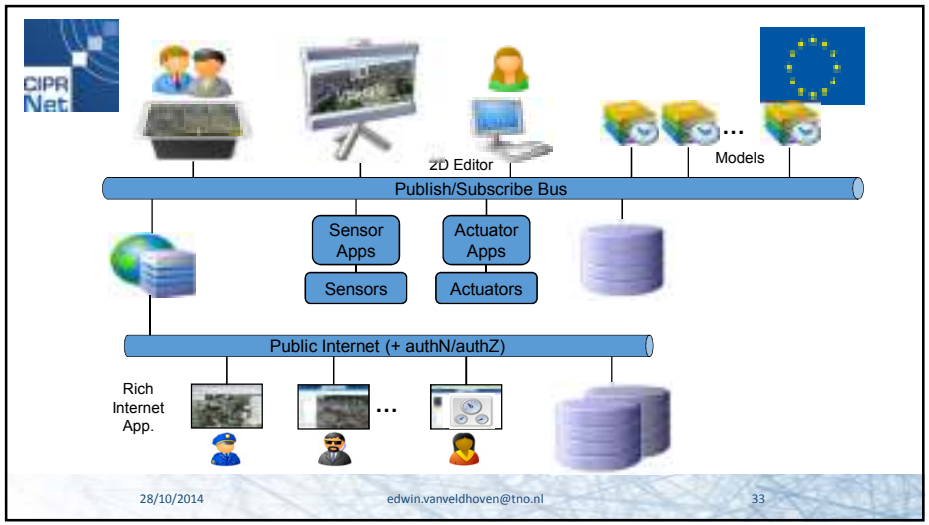
7. Analyse data and evaluate results

Analyse and evaluate data acquired during the execution of the simulation environment, and report the results back to the user/sponsor.

Activities include:

- Analyse data
  - Apply analysis methods and …
  - Define appropriate presenta…
  - Prepare data in chosen form…
- Evaluate and feedback resu…
  - Determine if all objectives h…
  - Provide feedback and conclu…





M&S standards categories

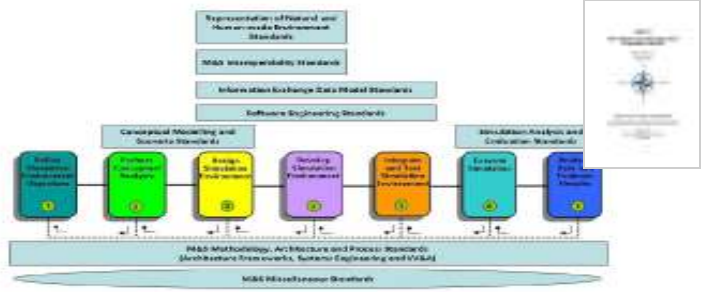
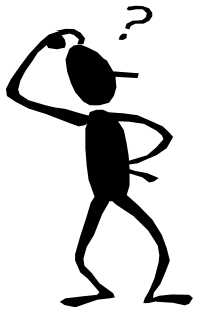


Figure 3-1: The 7-step DSEEP simulation engineering process and the standards categories

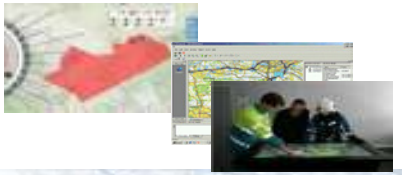
Promoting standards: does it work?



- **Advantages**
  - **Economy of scale**
  - **Comply with legislation**
  - **Promote interoperability**
  - **Promote common understanding**
  - **Introduce innovations, transfer research results**
  - **Encourage competition**
  - **Facilitate trade**
- **Challenges**
  - **Consensus**
  - **Not-invented-here**
  - **Openness / vendor lock-in**
  - **Maintenance**

Summary

- M&S are complimentary areas of **problem analysis** and **solution synthesis**, which are needed to support the full life cycle of a capability
- A set of **coherent principles** and **standards** is required to fully exploit the potential of M&S



More information

- SISO website: http://www.sisostds.org
- NMSG website: http://www.cso.nato.int/panel.asp?panel=5

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Verification and Validation

Edwin van Veldhoven - TNO
edwin.vanveldhoven@tno.nl

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

UCBM Headquarters – Rome (Italy) – 10-11 July 2014

This lecture is about three things:

- You have to do V&V
  - because there is risk involved
- You have to do V&V in a structured way
  - if you want to do it more effective and more efficient
- You have to choose the right V&V technique
  - in order to balance the risk with the effectiveness and efficiency

Part 1

- You have to do V&V
  - because there is risk involved
- You have to do V&V in a structured way
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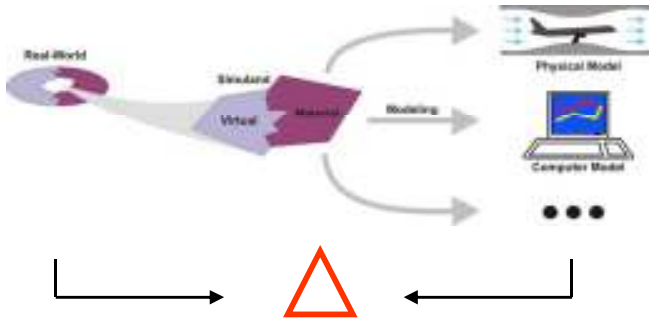
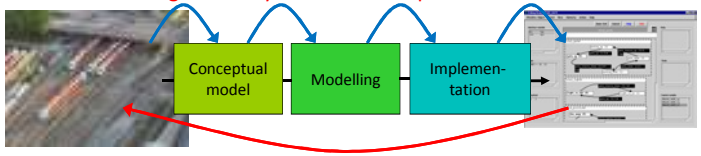
What is 'Modelling and Simulation' (M&S)?



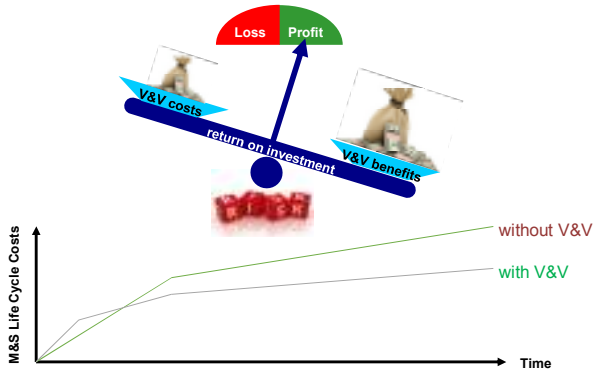
What is 'Verification and Validation' (V&V)?

- Verification
  - assesses if the M&S system is built and used right
- Validation
  - assesses if the right M&S system is built or procured



Provides insight into and advice on the quality of the M&S system over its entire life cycle, and the associated risks

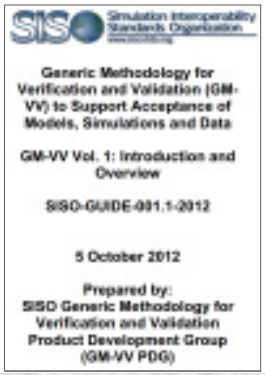
Should you always do V&V?



Part 2

- You have to do V&V
  - because there is risk involved
- You have to do V&V in a structured way
  - if you want to do it more effective and more efficient
- You have to choose the right V&V technique
  - in order to balance the risk with the effectiveness and efficiency

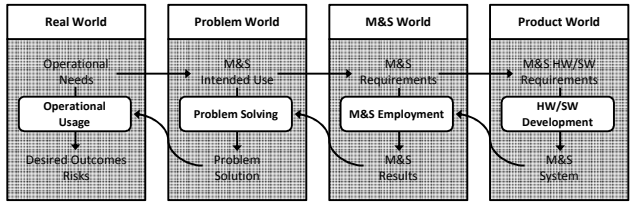
Structured approach to V&V



Generic Methodology for V&V (GM-VV)

- Conceptual framework
  - basis of GM-VV
  - connection to other V&V methods
- Implementation framework
  - products, processes, roles
  - technical, project, enterprise
- Tailoring framework
  - adaption
  - optimization

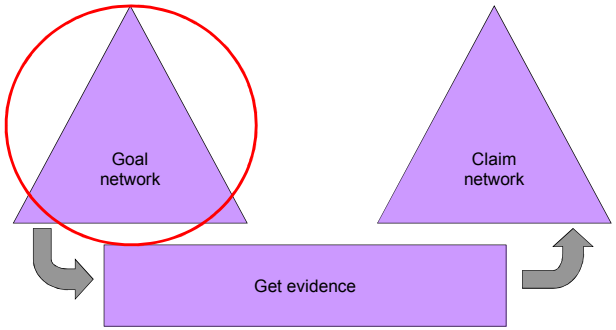
Four-worlds model



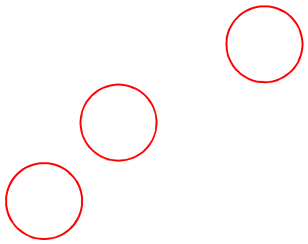
What needs to be V&V-ed for CIP?

- Simulators: power plants, banks, traffic generators, networks, ...
  - man-in-the-loop simulators
- Exercise management facilities
  - scenario development tools
  - briefing/debriefing tools
  - trainers
- Analysis and assessment tools
  - specialized analysis tooling
  - loggers
  - 3D viewers
  - generic didactic modules (scoring, computer assisted instruction)
- Network infrastructure
  - local
  - wide area
  - security/encryption
  - different architectures used

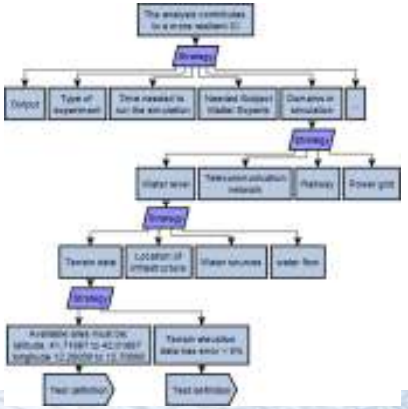
Argumentation network (1)



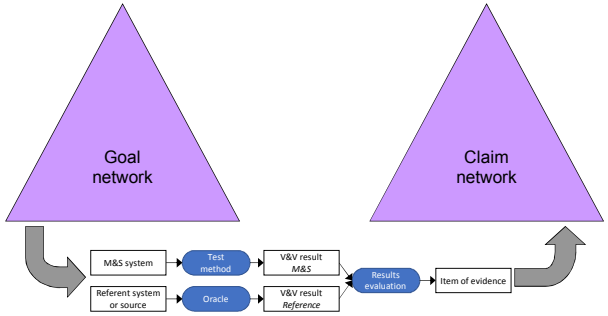
Argumentation network (2)



Argumentation network (2)

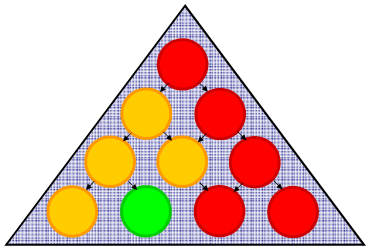


Argumentation network (3)

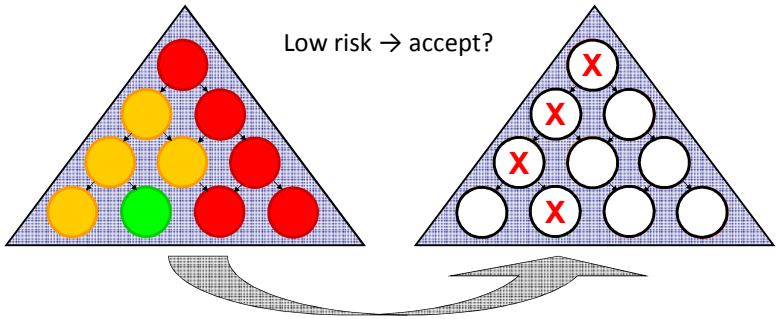


Risk decomposition

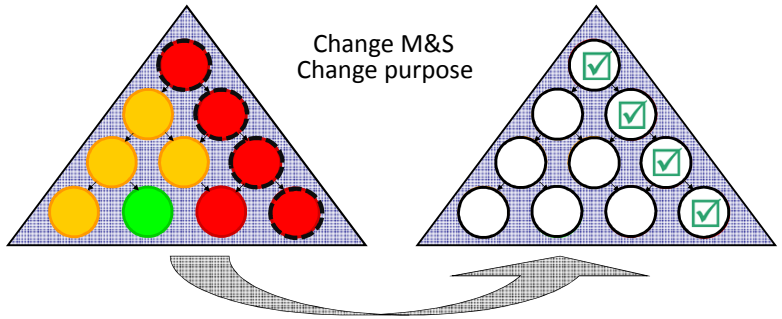
- Priorities
- Required certainty
- Specification of tests
  - resource distribution



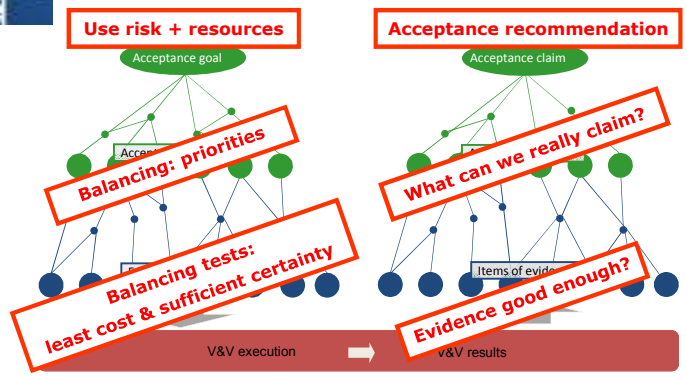
Not all criteria have been met! (1)



Not all criteria have been met! (2)



Project level



Enterprise level

- Execute and/or manage projects, provide training
- V&V expertise, tools, re-use, ...
- Q-tility is an implementation of the GM-VV enterprise level

Advantages of the structured approach (1)

- You start at the right point (effectiveness)
  - the risk of the user who applies the M&S results in the real world
- Re-usable domain knowledge (efficiency & effectiveness)
- Distribute the V&V work among all partners (efficiency)
  - V&V your own simulator (or you can assign it to another partner!)
- You can already do one branch of the Argumentation Network while waiting (efficiency)
  - you can already identify problems and fix them

Advantages of the structured approach (2)

- If a new M&S system replaces a current one, you know immediately which tests have to be performed (efficiency)
- You have a good idea of how complete your V&V work is (effectiveness)
  - at every disaggregation you have to show if it is complete or not
- You can assign priorities based on the risk (efficiency)
  - disaggregate the risk over the sub-nodes
- You can determine the required convincing force and assign resources such as budget, time, experts (efficiency)

Advantages of the structured approach (3)

- By standardizing the way the V&V work is documented, it is more easy to recall and re-use (efficiency)
  - re-use parts or the whole
  - no big problem if a key-person leaves your organization
- You can re-use the work over projects (efficiency)
  - if the M&S is re-used for a slightly different purpose, you can easily determine what additional tests have to be performed
  - add to what you already know → more and more complete → less chance you forget something (effectiveness)

Part 3

- You have to do V&V
  - because there is risk involved
- You have to do V&V in a structured way
  - if you want to do it more effective and more efficient
- You have to choose the right V&V technique
  - in order to balance the risk with the effectiveness and efficiency

How to choose the right V&V technique?

- Risk
  - the higher the risk, the more rigorous the technique
  - expected residual uncertainty
- Available means
  - budget, time, knowledge, testing facilities, ...
- Referent data
  - knowledge of the real world
- M&S system availability
  - access to development documents, M&S system internals

V&V techniques

- Balci [1998]
- Sargent [2010]
- M. Petty [2013]

4 basic categories of tests

- Informal
- Formal
- Static
- Dynamic

Informal tests

- Usually executed and interpreted by humans
- Typically few resources are required
- Convincing force depends on trust

- Techniques:
  - Audit, documentation checking, face validation, inspections, reviews, Turing test, walkthroughs

Formal tests

- Based on mathematical proofs of correctness
- Application often limited due to large resource costs
- Convincing force of the V&V results is very strong

- Techniques:
  - Induction, inductive assertions, inference, logical deduction, lambda calculus, predicate calculus, predicate transformation, proof of correctness

Static tests

- Can be applied early in the development process
- Typically specialized tools are used
- Required resources are normally limited
- Access to documentation and half-products is required
- Convincing force depends on the rigor of the test

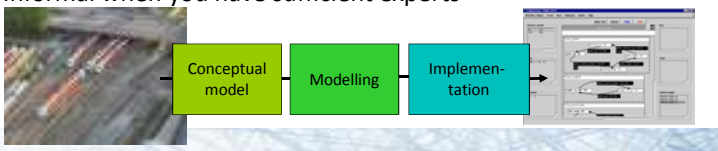
- Techniques:
  - Cause-effect graphing, control flow analysis, state transition analysis, data analysis, fault/failure analysis, interface analysis, semantic analysis, structural analysis, symbolic evaluation, syntax analysis

Dynamic tests

- Execution of (part of) M&S system is required
- Dynamic properties of the M&S system are studied
- Typically specialized tools are used
- Required resources are normally limited
- Access to internals of the M&S system may be required
- Convincing force depends on the rigor of the test
- Techniques:
  - Comparison testing, compliance testing, performance testing, security testing, standards testing, debugging, execution testing, fault/failure insertion testing

During development

- Static
  - models, design documents
- Dynamic when parts become available
  - (parts of) implementations
- Formal if you have sufficient resources
- Informal when you have sufficient experts



After development (but before use!)

- Dynamic
  - Components of the simulation, interoperability between components, emerging behaviour: cascading failures
- Informal
  - Face validation
  - Walkthroughs

"Take home" messages:

- You have to do V&V
  - because there is risk involved
- You have to do V&V in a structured way
  - if you want to do it more effective and more efficient
- You have to choose the right V&V technique
  - in order to balance the risk with the effectiveness and efficiency

References

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- Q-tility, q-tility.nl
- O. Balci, "Verification, Validation, and Testing", in J. Banks (Editor), Handbook of Simulation: Principles, Advances, Applications, and Practice, John Wiley & Sons, New York NY, 1998, pp. 335-393
- Mikel D. Petty, "Model Verification and Validation Methods", I/ITSEC tutorial 2013
- Robert G. Sargent, "VERIFICATION AND VALIDATION OF SIMULATION MODELS", Proceedings of the 2010 Winter Simulation Conference, B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yücesan, eds

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Geographical Information Systems for visualisation and analysis

Maurizio Pollino - ENEA
maurizio.pollino@enea.it

Modelling, Simulation and Analysis of Critical Infrastructures
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Geomatics

- The term ***Geomatics***(*) was created at Laval University in Canada in the early 1980s:
  - Geomatics is defined as a systemic, multidisciplinary, integrated approach to selecting the instruments and the appropriate techniques for collecting, storing, integrating, modeling, analyzing, retrieving at will, transforming, displaying, and distributing spatially georeferenced data from different sources with well-defined accuracy characteristics and continuity in a digital format.

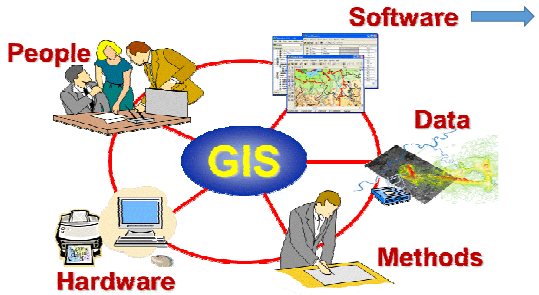
Most relevant elements of Geomatics:
- Geographical information system (GIS)
- Decision support system (DSS)
- WebGIS

(*)*Mario A. Gomarasca, (2009), Basics of Geomatics, Springer Netherlands, DOI 10.1007/978-1-4020-9014-1*
http://link.springer.com/book/10.1007%2F978-1-4020-9014-1

Geographic Information System

- We define **GIS (Geographic Information System)** as a structure constituted by a powerful set of instruments and technologies committed to acquire, store, manage, transform, analyze and visualize georeferenced spatial data.
  - Georeferenced information: every document or event referred to a particular portion of Earth's surface is an example of georeferenced information
  - Geospatial information: every document or event that is also represented from a cartographic point of view or by maps or aerial/satellite images is an example of geospatial information
- Often the two terms (georeferenced and geospatial) are used as synonyms.

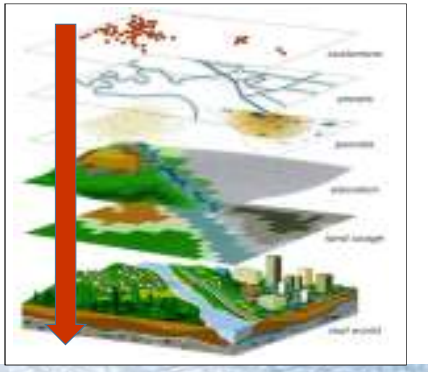
GIS elements and technology



- **Proprietary**
  - ✓ESRI ArcGIS
  - ✓Intergraph
  - ✓MapInfo
- **Free/Open Source (FOSS)**
  - QuantumGIS (QGIS) (http://qgis.org/)
  - GRASS GIS (http://grass.osgeo.org/)

How GIS works

- ✓ In a GIS, different types of information are represented as separate map layers, coming from different sources or disciplines (multidisciplinary)
- ✓ Each layer is linked to descriptive information
- ✓ Layers are numerically combined to make a new map containing further information
- ✓ Data modeling in environmental GIS:
  - Basic functionalities
  - Specific functionalities

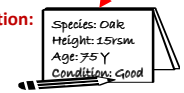


Geographic Information System

- **Spatial or geographic data represent REAL WORLD PHENOMENA and they are characterized by:**
  - their POSITION in space with respect to a reference and coordinate system;
  - NON-SPATIAL ATTRIBUTES (color, temperature, etc…);
  - mutual SPATIAL RELATIONS (topological, directional, distance relations).

- **We can describe any element of our world in two ways:**
  - **Location Information: Where is it?**

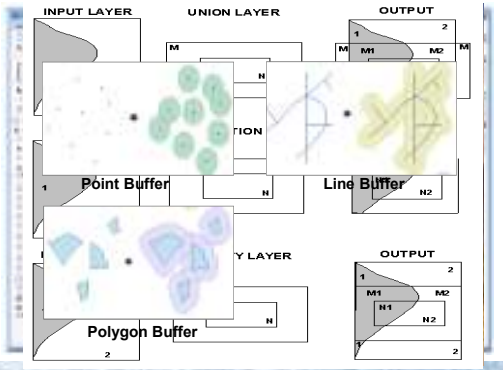
  - **Attribute Information: What is it?**



GIS Analysis Functions

Main categories:

- Visualization
- Retrieval, Classification and Measurement
- Overlay
- Extraction
- Proximity
- Map algebra (Raster)

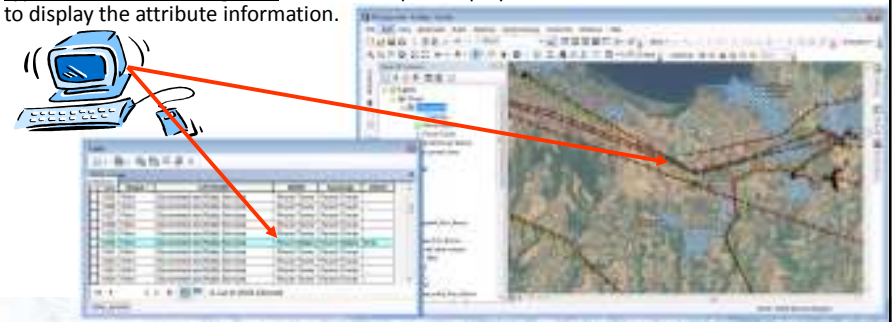


Methods of Spatial Data Analysis

- The GIS can perform a spatial analysis.
- Spatial relationships among the features and their attributes and the persistent link with their geometry (shape and position) make the GIS a tool able to simulate the real world and hence to help decision makers in solving actual problems.
- Operations can be carried out on a single data layer or by combining two or more data layers.
- They can be grouped in three categories:
  - Spatial data analysis;
  - Attributes analysis;
  - Integrated analysis.

GIS and DBMS

- The location and attribute information is stored inside your computer and a GIS links the two types of information together. It uses a map to display the location information and a table to display the attribute information.

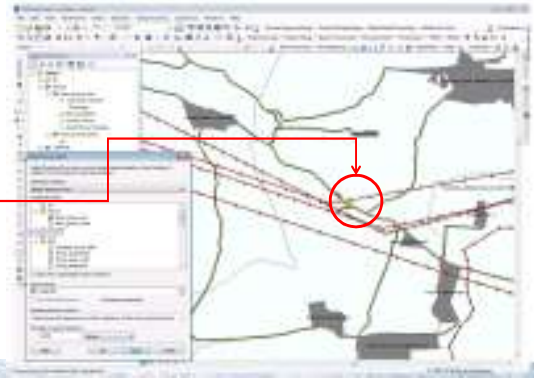


GIS query: example

- GIS software can answer questions about our world:

Spatial Questions:

Which Power Stations are closer than 1 km to a urban area?

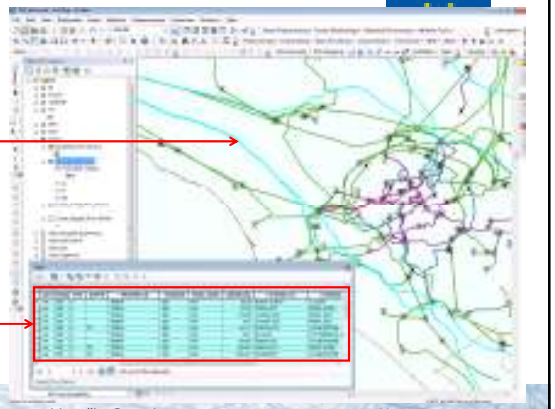


GIS query: another example

- GIS software can answer questions about our world:

Attribute Questions:

Select 380 kV high voltage transmission lines



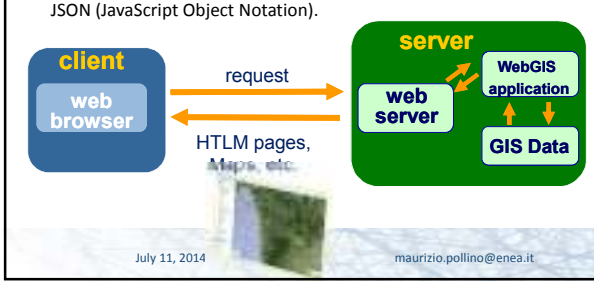
WebGIS and Web mapping

- Web mapping is the process of using maps delivered by GIS on the WWW, where it is both served and consumed. Web mapping is more than just web cartography, it is both a service activity and consumer activity.
- Web GIS is a type of distributed information system, comprising at least a server and a client, where the server is a GIS server and the client is a web browser, desktop application, or mobile application.
- In its simplest form, WebGIS can be defined as any GIS that uses web technology to communicate between a server and a client.
- Advantages: global reach, large number of users, not need to install/buy specific software, easy to use.
- WebGIS is commonly designed for simplicity, intuition, and convenience, making it typically much easier to use than desktop GIS.

WebGIS and Web mapping

Web GIS basic schema:

- The server has a URL so that clients can find it on the web.
- The client relies on HTTP specifications to send requests to the server.
- The server performs the requested GIS operations and sends responses to the client via HTTP.
- The format of the response sent to the client can be in many formats, such as HTML, binary image, XML or JSON (JavaScript Object Notation).



➢ Open Geospatial Consortium (OGC) standards:

Web Services
WCS: Web Coverage Service
WFS: Web Feature Service
WMS: Web Mapping Service
WMTS: Web Map Tile Service
WPS: Web Processing Service

Example: GIS-DSS Supporting the Response Planning to Disastrous Earthquake Events

- First information available immediately after a significant earthquake: magnitude and epicenter.
- Through geo-processing and visualization tools, this information together with shaking maps overlaid with inventories of critical facilities, highways and bridges, and vulnerable structures can effectively support the response planning.
- The interactive DSS could support decision makers and responders activities, related to emergency management, damage evaluations for buildings and lifelines, consequences for population.
- The WebGIS interface allows to visualize and analyse the geo-spatial data and thematic maps by means of basic GIS functionalities.

GIS-DSS Supporting the Response Planning to Disastrous Earthquake Events

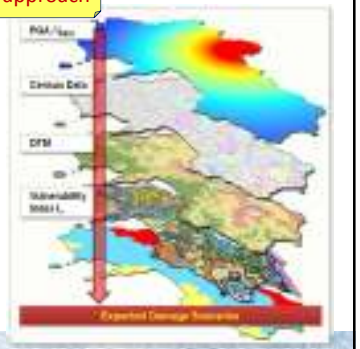
Spatial analysis procedures and geo-processing operations:

- Description and characterization of the study area (Geodatabase);
- Data management (Geomorphology, Seismic Risk, Census, Facilities and CI location, etc.);
- Shake maps processing (PGA/I_{MCS});
- Production of Vulnerability maps
- Elaboration of Harm Scenarios.

Results:

- Thematic maps to support the management of near/post-event phases;
- Consultation via intranet/internet to data and maps.

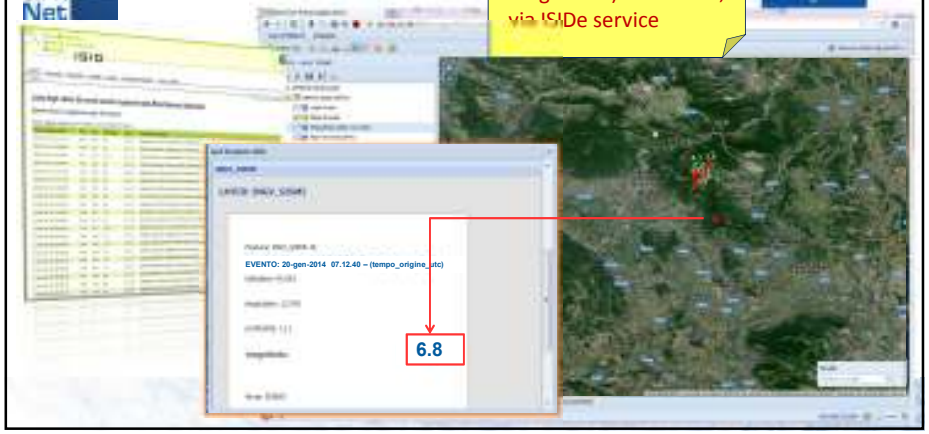
➢ GIS approach



Earthquake Event – Step 1

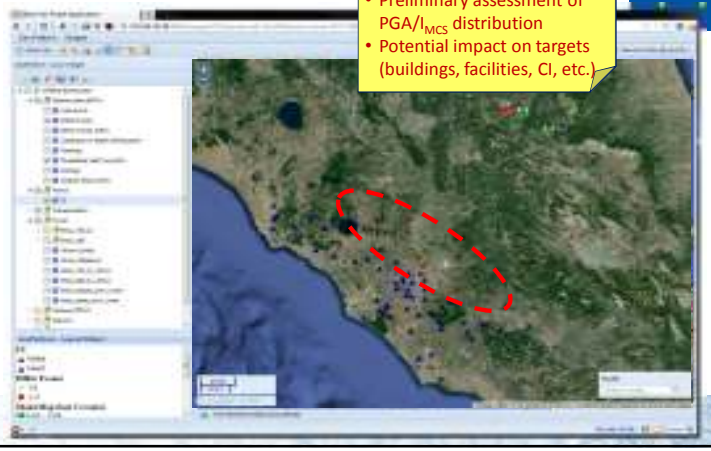
(T_0 ÷ few minutes)

- Get event data (Epicentre and Magnitude) from INGV, via ISIDe service



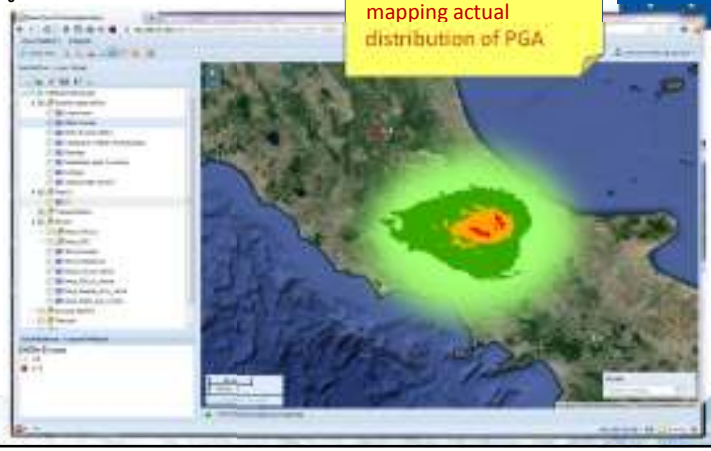
Earthquake Event – Step 1
(T_0 ÷ few minutes)

- Theoretical Shake-Maps production
- Preliminary assessment of PGA/I_{MCS} distribution
- Potential impact on targets (buildings, facilities, CI, etc.)



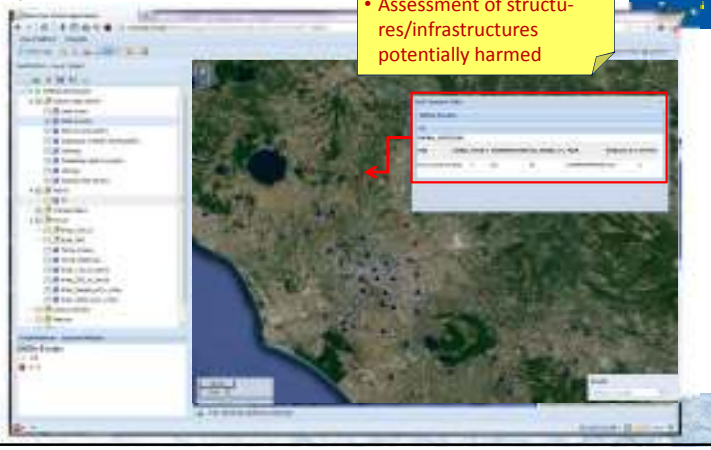
Earthquake Event – Step 2
(T_0 ÷ 1-2 hours)

- Get Measured Shake-Maps from INGV: mapping actual distribution of PGA



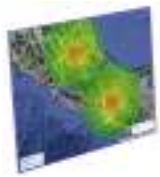
Earthquake Event – Step 2
(T_0 ÷ 1-2 hours)

- Impact on CI after the main shock
- Assessment of structu-res/infrastructures potentially harmed



Earthquake Event – Step 2
(T_0 ÷ 1-2 hours)

- **Earthquake** event data (Epicentre and Magnitude) and **Shake Maps** from INGV
- Actual distribution of PGA. PGV and I_{MCS}



- Use vulnerability matrices to perform a **refined assessment** of potential **Harm Scenario**

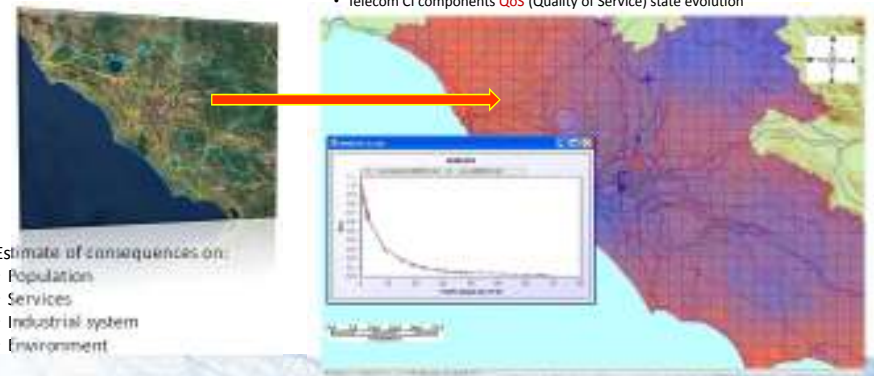
- Impact on CI after the main shock
- Elaboration of **CI response** on "system of systems" models

Earthquake Event – Step 2

(T_0 ÷ 1-2 hours)

Example:

- Telecom CI components QoS (Quality of Service) state evolution



Estimate of consequences on:

- Population
- Services
- Industrial system
- Environment

Conclusions

- We have presented an example of implementations of GIS-Based DSS in the framework of risk analysis.
- The unifying picture is the awareness that the inclusion, in the DSS workflow, of a capability of predicting environmental threats and that of considering the environment as a propagator of perturbations is a key ingredient for the effectiveness of these systems.
- This approach to risk analysis is intrinsically multidisciplinary, as it involves the clustering of a number of expertise, from those related to CIs to those of Geomatics, weather forecasting, oceanography, seismology etc.
- This approach will certainly foster a new generation of risk assessment/management tools which will enable an easier and more effective management of crises.

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Prediction of natural hazards

Annette Zijderveld – Deltares (with Deltares colleague contributions)
Annette.zijderveld@deltares.nl

Modelling, Simulation and Analysis of Critical Infrastructures
Master Class (Edition1)

UCBM Headquarters, Rome (Italy) – July 10-11,2014

Overview lecture

- Weather forecasting
- Flood forecasting
- Real-time levee strength
- Landslide forecasting
- Data-model integration
- Probabilistic forecasting
- Forecasting process and lead time
- Real-time forecast/ information services

Hazards –what can we predict?

Flash floods
Local precipitation of high intensity

Coastal flooding
Spring tides and storm surge

caused by rain or wind

Weather forecast

Landslide
Heavy long lasting precipitation / snow melt

Large scale flooding
Heavy long lasting precipitation / snow melt

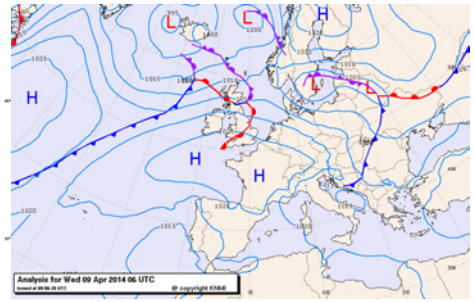
Weather forecast models

Time frame
Now-casting
Short range
Medium range
Monthly
Seasonal

Spatial coverage
Global
Regional
Downscaling to local level

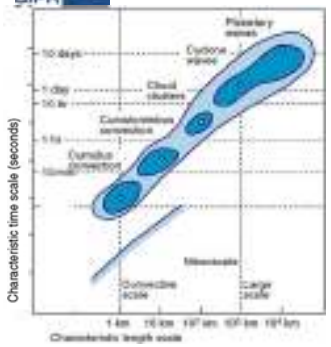
Modelling concepts
→ Deterministic models – 1 model run
→ Probabilistic models (ensemble of model runs)

Difference between models largest in extreme situations!



Source: KNMI, regional HiRLAM model

Weather forecasts: predictive skill



Relation between atmospheric scale and time scale (adapted from ECMWF website)

Time Range	0-12h	12 - 48 h	48 - 120 h
Type of Warning	WARNING	Pre-WARNING	Early WARNING
Product/ Area	**Actual local warnings**	**Regional warnings**	**Weather risk forecast**
Based on	Observations, Now-casting, Short range forecasting models	Deterministic and probabilistic models	Probabilistic models

Weather forecast example

- Numerical Weather Prediction grids in **FEWS-NL** (Rhine):
- **KNMI-HIRLAM**
  - 48 hrs lead time
- **DWD-LM2**
  - 78 hrs lead time
- **DWD-GME** (global)
  - 174 hrs lead time
- **ECMWF deterministic**
  - 240 hrs lead time
- **ECMWF ensemble**
  - 240 hrs lead time
  - 51 ensemble members
- **COSMO LEPS** (Limited-area Ensemble Prediction System)
  - 160 hrs lead time
  - 16 ensemble members

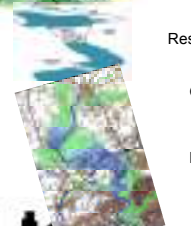
Dutch forecast system at RWS, weather forecast for River Rhine

Flood modelling

Numerical Weather prediction models

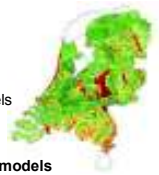
Rainfall-runoff modelling & snow modelling

Routing models
Hydrodynamic models



Reservoir Models

Groundwater models



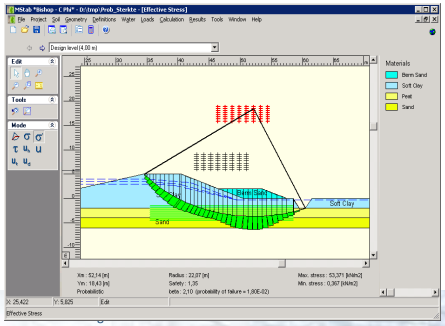
Flood inundation models

Urban drainage models

Coastal shelf models (2D Hydrodynamic)

Real-time forecasts of levee strength

Slope stability: depends on water level history

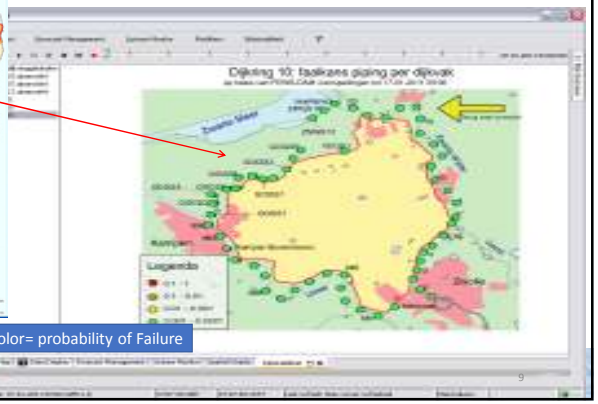


- Numerical models available
- Model run fast enough
- Real-time data possible

Supports decisions on prevention, mitigation and remediation

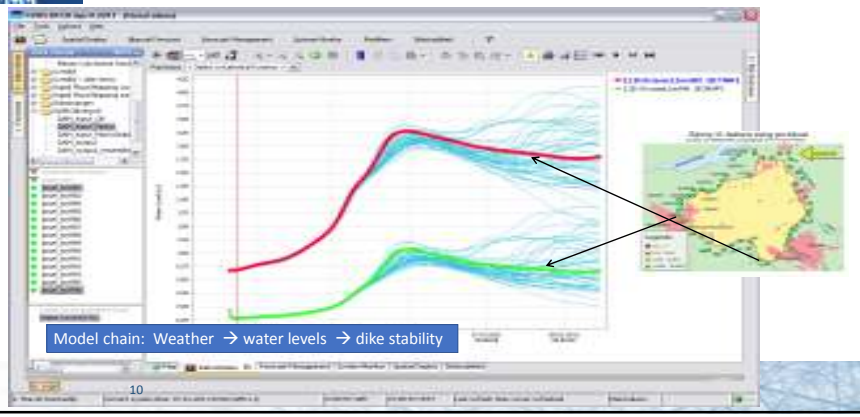
Real-time forecasts of levee strength

Example IJssel Lake, NL



Color= probability of Failure

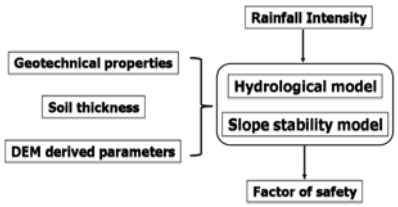
Real-time forecasts of levee strength



Model chain: Weather → water levels → dike stability

Landslide prediction

- Combination of different information sources and models
- Rain intensity and location important



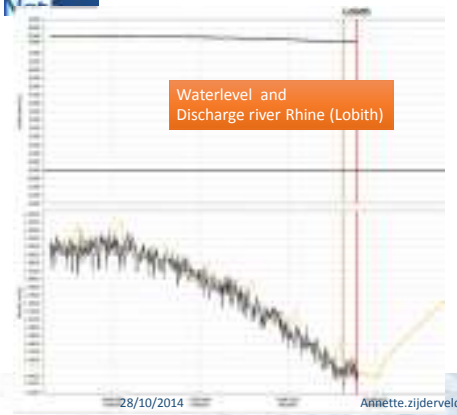
Forecast chain after S. Segoni et al, 2009

Source: SIMAnet

Measurement data

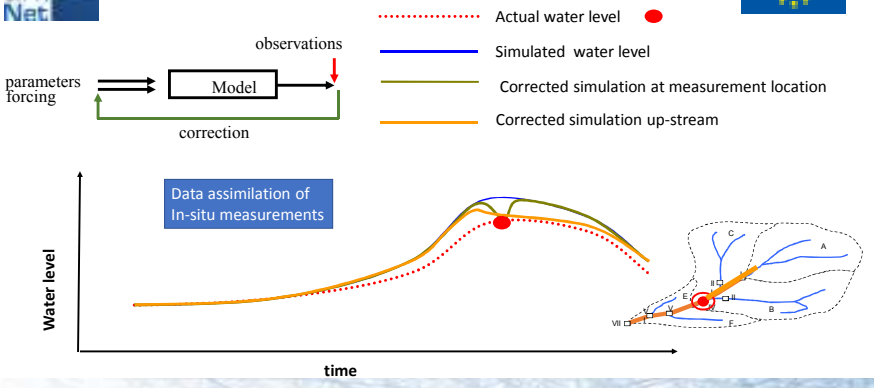
- Data availability increasing
- New sensor techniques
- Satellite information

Measurement data



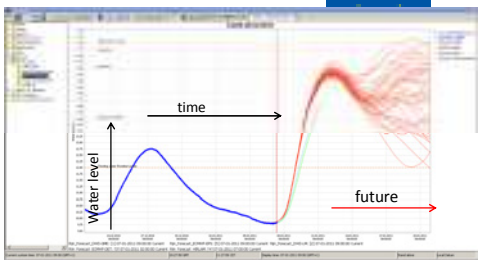
- Data quality remains an issue
- Measurements ≠ truth , checks and common sense stay necessary
- Big Data – new ways necessary to organize data

Data-Model integration



Uncertainties

Uncertainties caused by:
- Model uncertainties in all models
(Initial conditions or model parameters)
- Measurement uncertainties

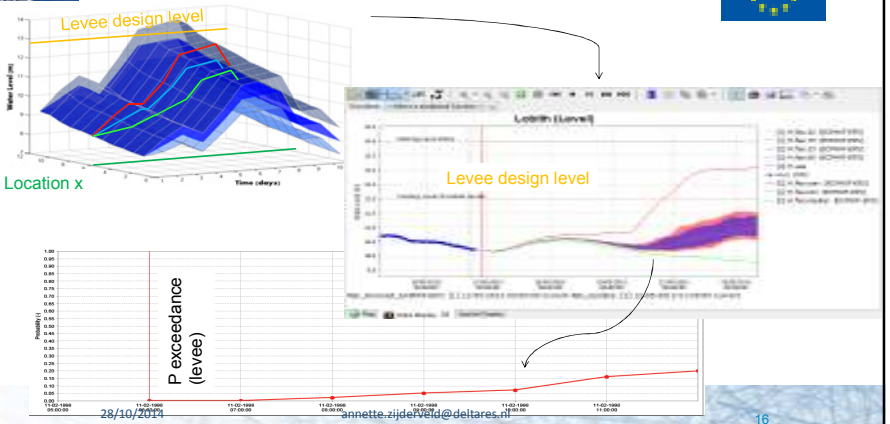


Lobith, Rhine

Probabilistic forecasting
Ensembles created by:
- Weather model run with different initial conditions
- Combination of different weather model runs in time
- Combination of different deterministic models
(poor-mans ensemble)

Uncertainty not less, but visible!

Should I stay or should I go?



"Prospect theory"

Which of the following would you prefer?

A: 50% chance to win 1,000, 50% chance to win nothing;

B: 450 for sure.

- Expectation values:

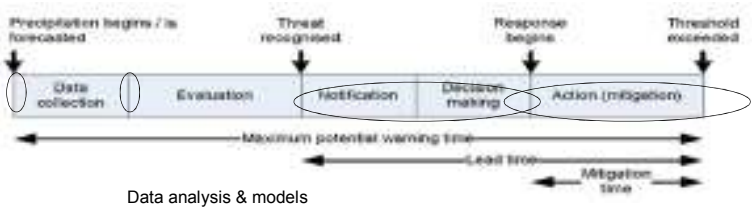
A: 50% x 1,000 + 50% x 0 = 500

B: 100% x 450 = 450

But still, more people chose B rather than A.

Concept of Lead time

Influencing factors



Data analysis & models

Carsell 2004; Verkade, 2008

Concept of Lead time

Impact of meteorology, hydrology and river hydraulics on lead time

Desired lead times en response times

T_d : Desired lead time

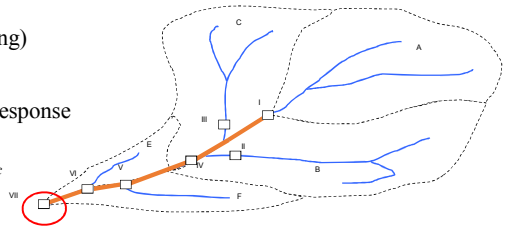
T_s : hydrologic response (runoff)

T_c : Response river system (routing)

Category 1

Warning based on river system response

$T_d < T_c$ and $T_s << T_c$



Concept of Lead time

Impact of meteorology, hydrology and river hydraulics on lead time

Desired lead times en response times

T_d : Desired lead time

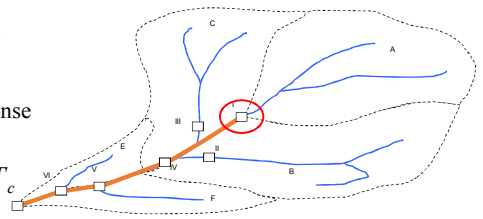
T_s : hydrologic response (runoff)

T_c : Response river system (routing)

Category 3

Warning based on hydrologic response

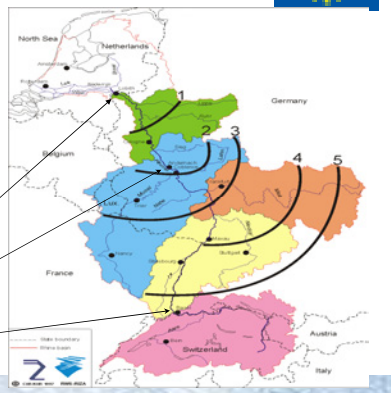
$T_d < T_c + T_s$ and $T_s >> T_c$



Concept of Lead time

Examples: Response times of the river Rhine

- Maximum response time of the flood wave is +/- 5 days
- Discharge entering NL at Lobith
- Largest contributions from the rivers Moselle and Main



Lead times not changed easily!

Concept of Lead time

Examples: coastal storm surges

- Tropical storm or North Sea: different behaviour
- Changes in tracks create uncertainty

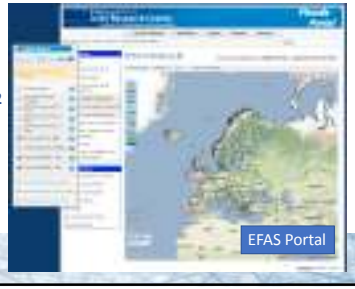
NW- storm at 5th December 2013
Higher water levels at UK coast than 1953
Highest water levels after 1953 in Belgium,
15 casualties in NW Europe

Source: KNMI (NL)

Available Forecasts in Europe

- Global Flood Awareness System (GloFAS) http://www.globalfloods.eu/en/
- Global Flood Partnership (GFP) http://portal.gdacs.org/Global-Flood-Partnership
- Copernicus Emergency Management Service (GMES) http://www.copernicus.eu/
- European Flood Awareness System (EFAS) http://floods.jrc.ec.europa.eu/efas-flood-forecasts.html
- National Forecasting Centres (Meteo/ Hydro)
- Civil Protection Agencies
- INGV (earthquake, Italy) http://terremoti.ingv.it/en
- CSEM-EMSC (earthquake, Europe) http://www.emsc-csem.org/#2

Output of Real-time Event Forecasting System
→ input for Decision Support System



Take home

- Hazard prediction always combination of available measured data and model simulations, using different concepts
- Numerical model systems dominant in forecasting systems
- Probabilistic forecasting creates awareness of uncertainties
- Leads times for warning depended on system behaviour
- Real-time services are increasing: both in quality as well in lead-time for different type of hazards
- Translation for CI consequences still a challenge in real-time (DSS)


Thank you for your attention!
28/10/2014
annette.zijderveld@deltares .nl
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CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

Hybrid Engineering/Phenomenological Approach to Simulate System of Systems

José R. Marti[1]– The University of British Columbia, Vancouver, Canada / Alberto Tofani[2] – ENEA, Rome, Italy

[1] jrms@ece.ubc.ca, [2] alberto.tofani@enea.it

Modelling, Simulation and Analysis of Critical Infrastructures
CIPRNet Course

UCBM Headquarters – Rome (Italy) – 10-11 July 2014

CSILab

Presentation

1. World Models
2. Divide et Impera
3. i2Sim Multi-system Engineering/Phenomenological Modelling
4. DR-NEP Federated Simulation
5. Appendix: Sample Scenarios

World Models | Divide et Impera | i2Sim | DR-NEP

World Models

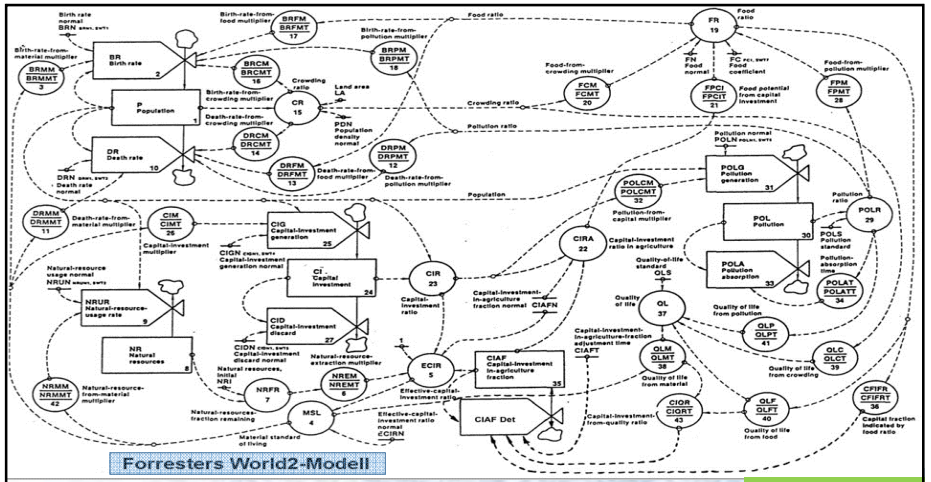
Represent processes to produce goods and services to support human well-being

- **Forrester System Dynamics World Model (1961)**
  - Prof. Jay Wright Forrester, b. Nebraska, Electrical Engineering degree, MIT, Professor Management, MIT.
- **Leontief Input/Output Production Model (1951)**
  - Prof. Wassily Leontief, b. Munich, Economics degree, Leningrad, Professor Economics, Harvard, New York, Nobel Prize Economics (1973).
- **i2Sim Interdependencies World Model (2004)**
  - Complex Systems Integration (CSI) Laboratory, UBC, Canada.
- **Other Models[1]**

[1] Jamshidi, Mo, Editor (2009) System of Systems Engineering, Innovations for the 21st Century, Wiley

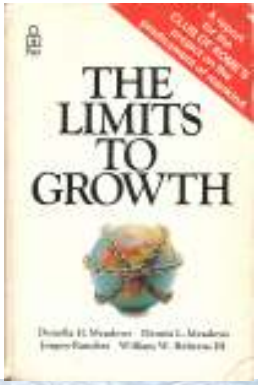
Forrester's World Model (1961)

- Based on control systems theory. Includes positive and negative feedback loops to relate production and consumption variables at a macroscopic level.
- It is a flat world model where all processes occur in the same layer.
  - The food system
  - The industrial system
  - The population system
  - The non-renewable resources system
  - The pollution system



The Limits to Growth (1972)[1]

- Based on Forrester's World 2 model.
- It predicts that the limits to growth on this planet will be reached within the next one hundred years.
- Reviewed (2004): We are on track with the predictions!



[1] Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, and William W. Behrens III (1972). Universe Books

Leontief's World Model[1] (1951) (Nobel Prize 1973)

- Uses input-output tables to relate the amount of input resources needed for a given amount of finished product.
- To manufacture 10 cars we need ten engines, 40 tires, etc. If we only have 5 engines, we can only build 5 cars. The engines, tires, etc. are inputs to the factory. The tires are the output of some other factory that requires rubber as an input, etc.
- It is a flat model that assumes a linear relationship between parts and units produced.

[1] Leontief, Wassily (1986) Input-Output Economics, 2nd ed., Oxford University Press

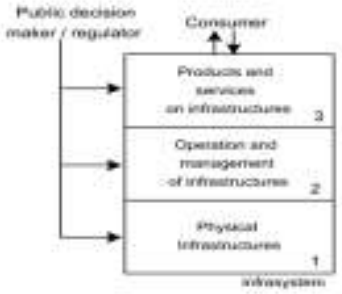
Leontief's World Model

		1	2	3	4	5	6	7	8	... 42
agriculture and fisheries	1	10.86	15.70	2.16	0.02	0.19		0.01		
food and kindred products	2	2.38	5.75	0.06	0.01	•	•	0.03	•	
textile mill products	3	0.06	•	1.30	3.88	•	0.29	0.04	0.03	
apparel	4	0.04	0.20		1.96		0.01	0.02		
lumber and wood products	5	0.15	0.10	0.02	•	1.09	0.39	0.27	•	
furniture and fixtures	6			0.01			0.01	0.01		
paper and allied products	7	•	0.52	0.08	0.02	•	0.02	2.60	1.08	
printing and publishing	8		0.04	•					0.77	
chemicals	9	0.83	1.48	0.80	0.14	0.03	0.06	0.18	0.10	
products of petroleum and coal	10	0.46	0.06	0.03	•	0.07	•	0.06	•	
rubber products	11	0.12	0.01	0.01	0.02	0.01	0.01	0.01	•	
leather and leather products	12			•	0.05	•	0.01		•	
stone, clay, and glass products	13	0.06	0.25	•	•	0.01	0.03	0.03		
primary metals	14	0.01	•		•	0.01	0.11		0.01	
fabricated metal products	15	0.08	0.61	•	0.01	0.04	0.14	0.02	•	
machinery (except electric)	16	0.06								
electrical machinery	17									
motor vehicles	18	0.11								
other transportation equipment	19	0.01								
... 42										

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{c} \Leftrightarrow \left\{ x_i = \sum_j a_{ij} x_j + c_j \right\} \forall\, i$$

Hierarchical Models

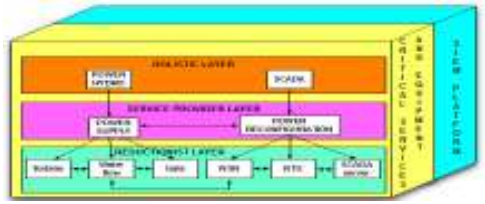
- Thissen and Herder (2009)[1] propose that a system of systems can be described using hierarchical layers:
  - Physical Layer
  - Operations and Management Layer
  - Products and Services Layer
  - Consumer Layer
  - Public Decisions Layer



[1] Thissen, Wil A.H., Herder, Paulien M. (2009). In: System of Systems Perspectives on Infrastructures, Chapter 11 in System of Systems Engineering, Innovations for the 21st Century, Jamshidi, Mo, Editor, Wiley.

Mixed Holistic Reductionist Layers1

- De Porcellinis, Panzieri, and Setola have applied MHR in risk analysis to identify equipment and services as related to Critical Infrastructures.



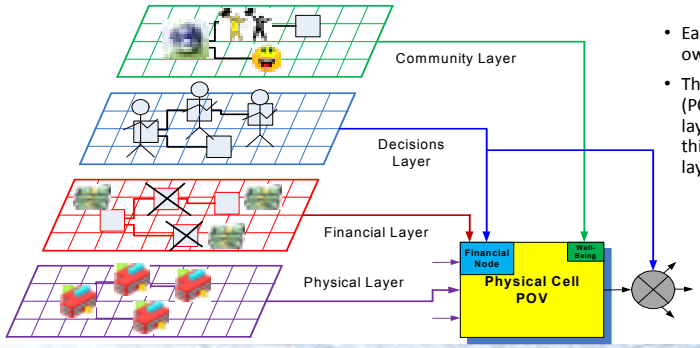
[1] S. De Porcellinis, S. Panzieri, and R. Setola, Modeling critical infrastructure via a mixed holistic reductionist approach, International Journal of Critical Infrastructures, vol. 5(1/2), pp. 86-99, 2009

i2Sim World Model[1] (UBC, 2004)

- Extends Leontief's production model by including nonlinear factors and phenomenological factors into the production process.
- In addition to engines, tires, etc. to produce cars, we need workers, electricity, equipment, building, money to buy the parts, etc. These "components" cannot be factored out linearly into the final product. Building, lights, and workers are needed in times of high production or low production.
- Human factors like tiredness, enthusiasm, cannot be factored out into Leontief's production functions but can be included in i2Sim.

[1] Marti JR (2014) Multisystem Simulation: Analysis of Critical Infrastructures for Disaster Response. In: D'Agostino G, Scala A (eds) Networks of Networks: The Last Frontier of Complexity, Springer, Heidelberg, p 255-277

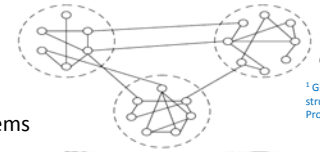
Stack of Infralayers



- Each infralayer has its own production cells.
- The Point of View (POV) of a cell in a layer interconnects this layer to the other layers.

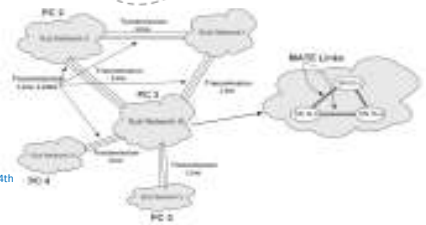
Divide et Impera

- "Divide et impera" (divide and conquer) (Julius Caesar, 100 BC)
- Establish self-sufficient subsystems with "help" through links when needed.



Community Structure Theory[1]

[1] Girvan M, Newman MEJ (2002) Community structure in social and biological networks. In: Proceedings of the National Academic of Sciences

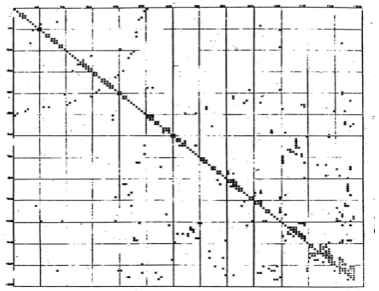


Multi-Area Thévenins (MATE)[2]

[2] Martí JR et al (2002) OVNI: Integrated Software/Hardware Solution for Real-Time Simulation of Large Power Systems. In: Proc. 14th PSCC, Seville, Spain, June 24th – 28th, 2002

North American Power Grid

(Easter System, Western System, Quebec System, and Texas System)



WECC System [Y] matrix (14,327 busses, 16,607 branches)

(Notice Sparsity)

Partition into Node and Link Equations[1]

$$
\begin{array}{c|cccc|ccc|c|c}
 & \text{A1} & \text{A2} & \text{A3} & \text{A4} & \text{B1} & \text{B2} & \text{B3} & & \\
\text{A1} & G_{A11} & G_{A12} & 0 & G_{A14} & & & & v_{A1} & h_{A1} \\
\text{A2} & G_{A12} & G_{A22} & G_{A23} & 0 & & & & v_{A2} & h_{A2} \\
\text{A3} & 0 & G_{A23} & G'_{A33} & G_{A34} & G_{A3B1} & & & v_{A3} & h_{A3} \\
\text{A4} & G_{A14} & 0 & G_{A34} & G'_{A44} & & & G_{A4B3} & v_{A4} & h_{A4} \\
\text{B1} & & & G_{B1A3} & & G'_{B11} & G_{B12} & G_{B13} & v_{B1} & h_{B1} \\
\text{B2} & & & & & G_{B12} & G_{B22} & G_{B23} & v_{B2} & h_{B2} \\
\text{B3} & & & & G_{A4B3} & G_{B13} & G_{B23} & G'_{B33} & v_{B3} & h_{B3}
\end{array}
$$

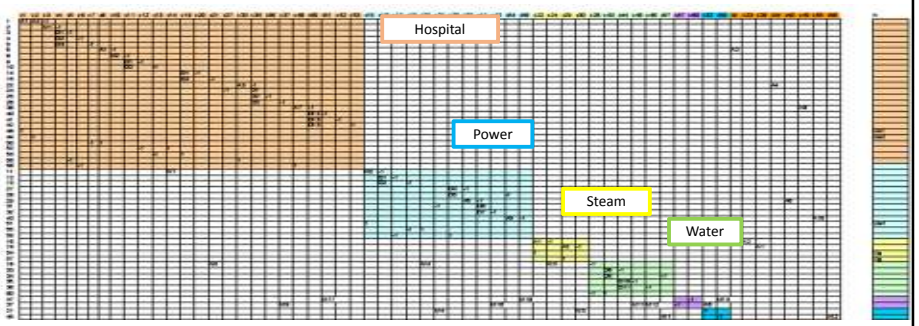
Normal

$$
\begin{array}{c|cccc|cccc|c|c}
 & \text{A1} & \text{A2} & \text{A3} & \text{A4} & \text{B1} & \text{B2} & \text{B3} & \alpha_1 \quad \alpha_2 & & \\
\text{A1} & G_{A11} & G_{A12} & 0 & G_{A14} & & & & 0 \quad 0 & v_{A1} & h_{A1} \\
\text{A2} & G_{A12} & G_{A22} & G_{A23} & 0 & & & & 0 \quad 0 & v_{A2} & h_{A2} \\
\text{A3} & 0 & G_{A23} & G_{A33} & G_{A34} & & & & 1 \quad 0 & v_{A3} & h_{A3} \\
\text{A4} & G_{A14} & 0 & G_{A34} & G_{A44} & & & & 0 \quad 1 & v_{A4} & h_{A4} \\
\text{B1} & & & & & G_{B11} & G_{B12} & G_{B13} & -1 \quad 0 & v_{B1} & h_{B1} \\
\text{B2} & & & & & G_{B12} & G_{B22} & G_{B23} & 0 \quad 0 & v_{B2} & h_{B2} \\
\text{B3} & & & & & G_{B13} & G_{B23} & G_{B33} & 0 \quad -1 & v_{B3} & h_{B3} \\
\alpha_1 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & -z_{\alpha 1} \quad 0 & i_{\alpha 1} & 0 \\
\alpha_2 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 \quad -z_{\alpha 2} & i_{\alpha 2} & 0
\end{array}
$$

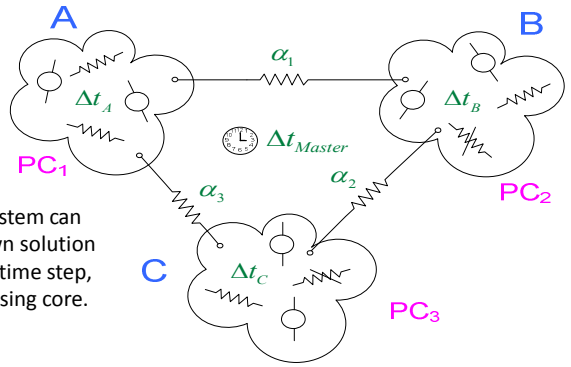
MATE

[1] Martí José R, et al (1998) OVNI: An object approach to real-time power system simulators. In: Proceedings of the 1998 International Conference on Power System Technology, Powercon'98, Beijing, China, August 18-21.

UBC Campus Infrastructures

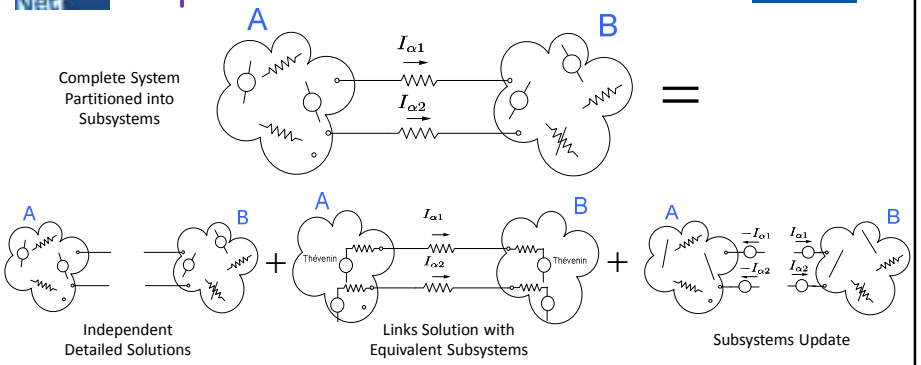


MATE Subsystems and Links



Each subsystem can have its own solution algorithm, time step, and processing core.

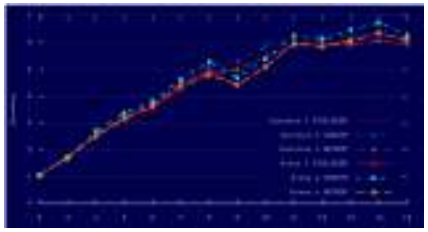
Total Solution = Internal + Links + Update



Parallel-MATE

WECC System[1]

Generic Multi-CPU with MPI Standard Interface

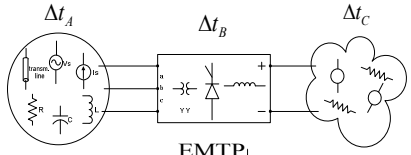


- 14,327 busses; 16,607 branches; 47,541 non-zeroes in admittance matrix
- 6.5 X speedup with 14 partitions and 14 processors, sparse solver used for all solutions

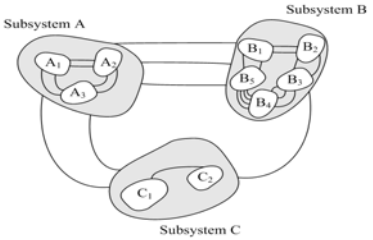
[1]Tomim, Marcelo (2009) Ph.D. Dissertation, UBC, March.

Multiple Time Constants and Multiple Depth

Different Time Constants



System Inside a System

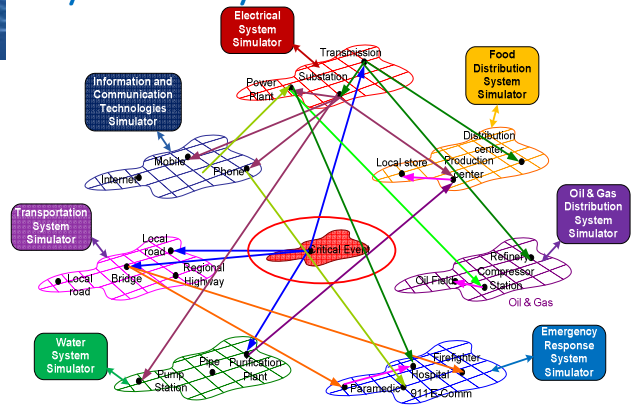


I2SIM REAL TIME FEDERATED SIMULATOR

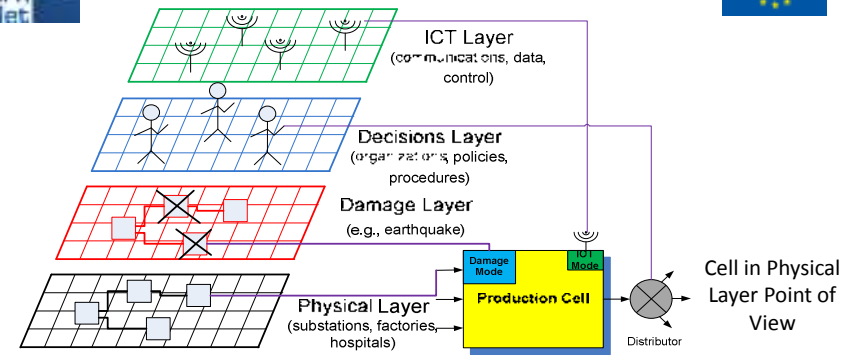
Critical Infrastructures in Canada

- Energy
- Water
- Food
- Manufacturing
- Finance
- ICT
- Transportation
- Health
- Safety & Order
- Government & Defence

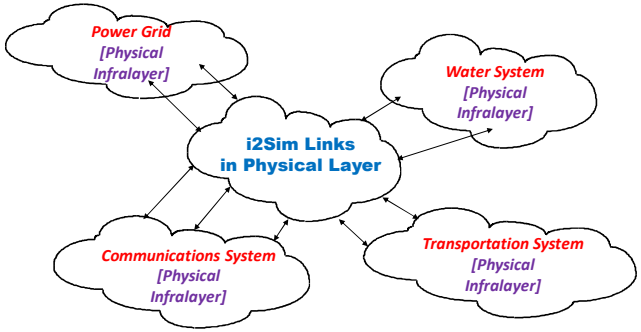
System of Systems of CI



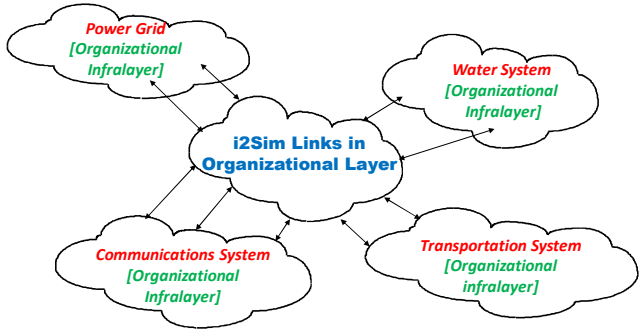
Each CI has Multiple Layers



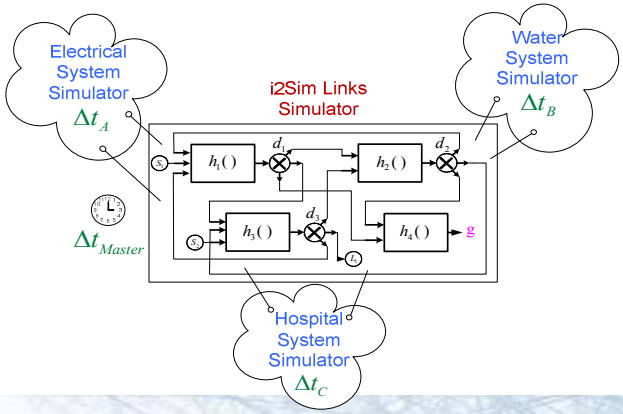
Physical Layer



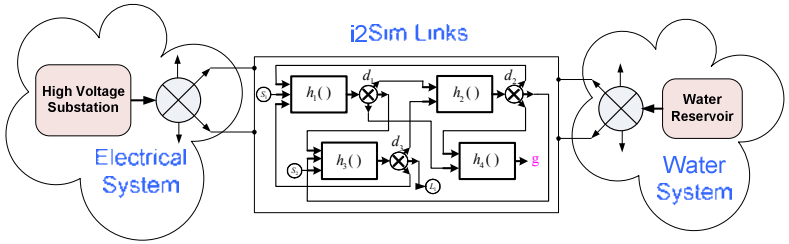
Organizational Layer



i2Sim "Links" the CI Simulators



Privacy of Information

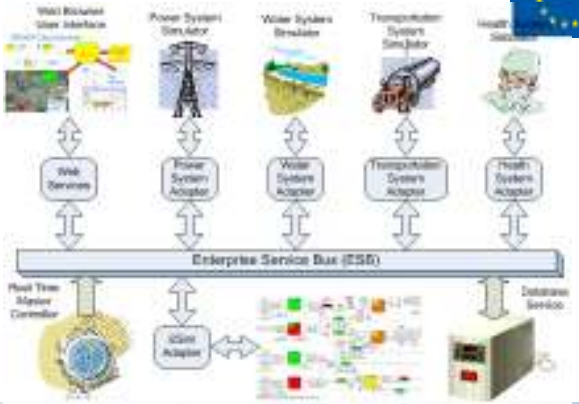


CI owners only need to provide point-of-entry information. They do not need to provide the internal physical details or the operational strategy of their system.

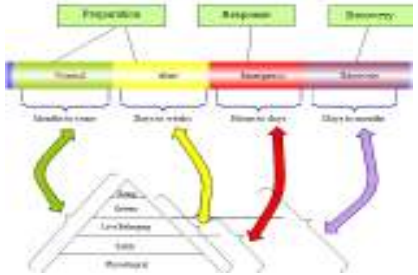
CI provide available point-of-entry resource (source) and a "Table of Choices" (distributor)

Federated Real-Time i2Sim Platform

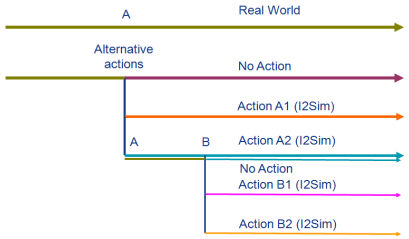
- Off-the-shelf simulators (or the internal CI simulators) can be used for the CI.
- Input/output of the simulators are translated by the Software Adapters.
- Communication with all other simulators takes place in the common ESB language.
- Additional simulators can be easily added by writing software adapter.



Disaster Real-Time Line

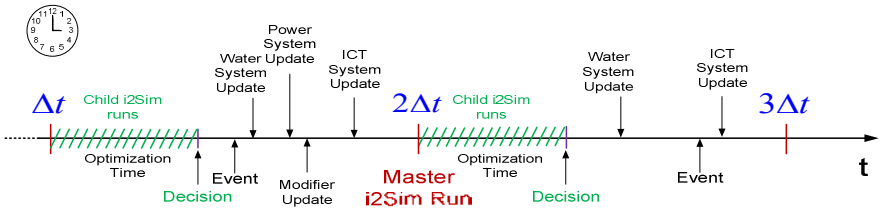


Disaster Timelines



Decisions are Needed when Events Occur

Real-Time Line is Driven by Scripted or Real Time Events



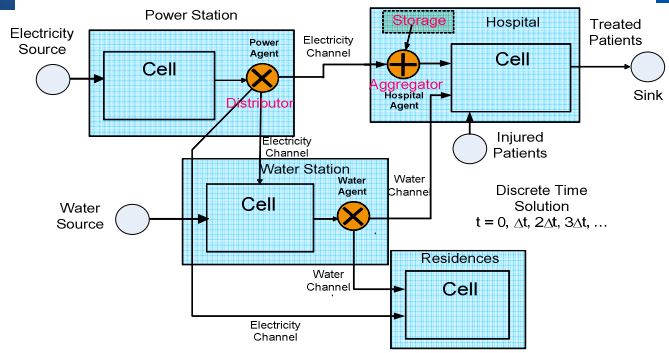
External simulators run at their own time-step. They are synchronized at the Master Clock intervals using MATE's multi-rate techniques.

Example: Japan Sendai Disaster Timeline[1]

No	Time (min)	Event
1	0	Normal conditions (fact)
2	46	Earthquake M = 9.0 (fact)
3	53	A tsunami warning is issued for the coastal area of Japan (fact)
4	54	An evacuation process is going on (fact)
5	75	The first tsunami wave hits the impact zone (fact)
6	95	Water retreats (fact)
7	160	Survivors start evacuating the impact zones (assumption)
8	220	Road are prepared to begin the triage, search and rescue process (assumption)
9	221	The process for transportation of survivors and casualties begins (assumption)
10	300	Ambulance dispatch goes down
11	400	Ambulance dispatch restored
12	500	Medical supplies depleted at serious injury hospitals
13	600	Additional medical supplies provided to serious injury hospitals
14	800	Food decreases at shelter

[1]William (Tiange) Wang (2012) M.A.Sc. Thesis, UBC.

i2Sim Ontology

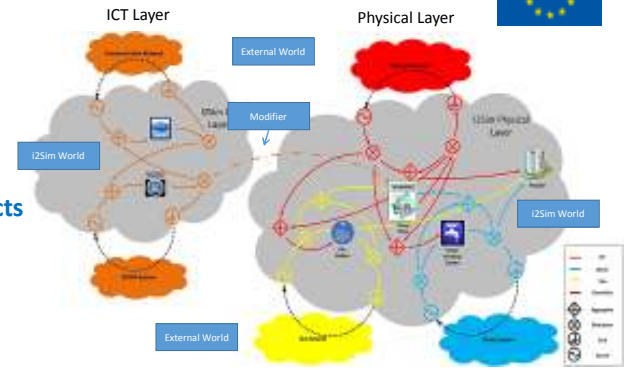


Basic Objects

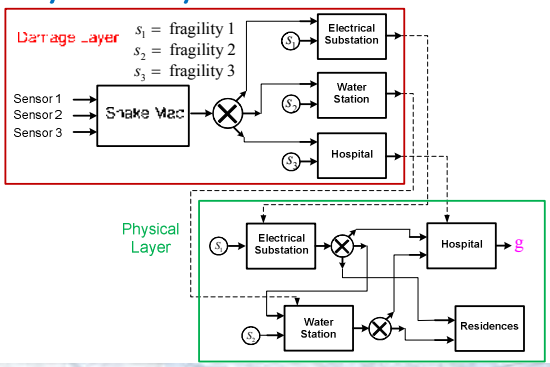
- **Tokens:** What "flows" in the system. Countable (e.g., ambulances) or Rates (e.g., liters/hr, KW, patients/hr).
- **Cells:** The production units. They take input tokens (e.g., electricity, engines, patients) and produce one output token (e.g., cars, treated patients).
- **Channels:** The conduits that carry the tokens (e.g., electrical cables, water pipes, roads).
- **HRT:** The Human Readable Table gives the functional relationship between the input tokens and the output token.

Other Objects

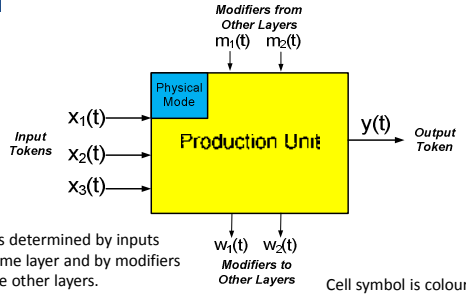
- **Controls**
  - Distributors
  - Aggregators
  - Storage
- **Exchange Objects**
  - Sources
  - Sinks
  - Modifiers



Example: Damage Layer with Physical Layer



i2Sim Production Cell

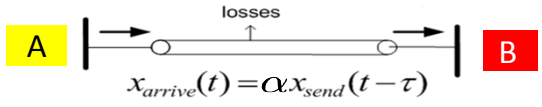


Output y(t) is determined by inputs x(t) in the same layer and by modifiers m(t) from the other layers.

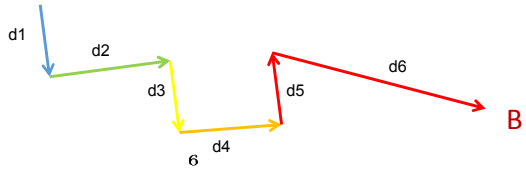
Colour	State
	100%
	75%
	50%
	25%
	0%

Cell symbol is colour coded. Upper left colour is the physical damage. Cell body colour is the output level.

Channel Abstraction



$$x_{arrive}(t) = \alpha x_{send}(t-\tau)$$

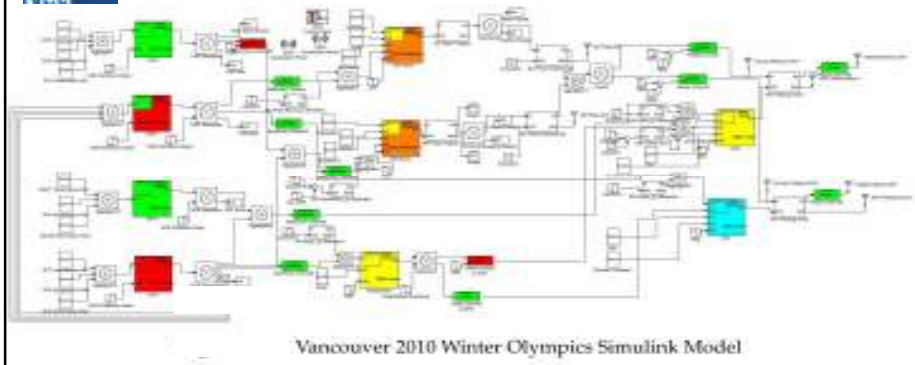


Multiple pipes are combined into a single equivalent channel

$$loss = \sum_{i=1}^{6} damage_i \times V_i$$

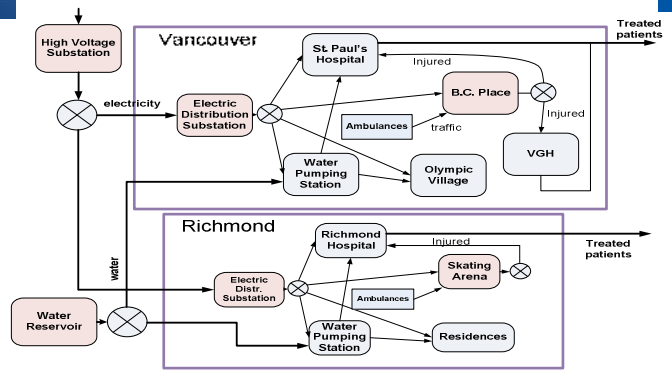
$$\alpha = 1 - loss$$

MATLAB/Simulink Implementation

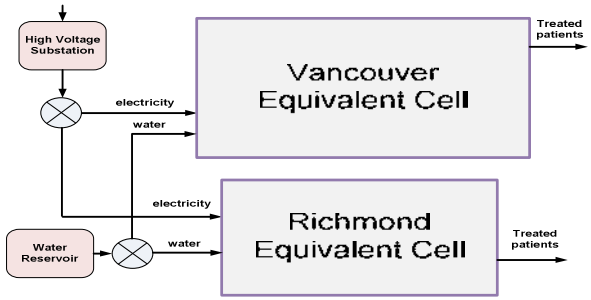


Vancouver 2010 Winter Olympics Simulink Model

Equivalencing for Coarser Resolution



High Level View



Sendai Disaster Zones

High-Level View

HUMAN READABLE TABLE (HRT) INTEGRATES ENGINEERING AND HUMAN EXPERIENCE

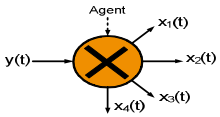
Electrical Substation

Cell HRT

Operability	y(t)	x(t)	Condition
	Low Voltage Power (MW)	High Voltage Power (MW)	Transformers Working
Green	200	200	2
Yellow	100	100	1
Red	0	0	0

Distributor Decision

Agent Decision: Choose 2 out of 4 feeders to supply
Implementation: Action on Breakers B1, B2, S1, S2, S3, S4



Water Pumping Station

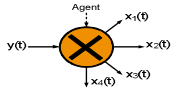
Cell HRT

	High Pressure Water (kL/h)	Low Pressure Water (kL/h)	Electricity (kW)	Pumps Working
	y(t)	$x_1(t)$	$x_2(t)$	
Green	500	500	50	10
Blue	350	350	35	7-8
Yellow	250	250	25	5
Orange	200	200	20	2-3
Red	0	0	0	0

- If the upstream water mains only provides 250 kL/h then, assuming electricity is available, regardless of whether 5 or more pumps are working, the output will be 250 kL/h.

Distributor Decision

- Since only four pipes are going out, assuming 125 kL/h on each, if 5 pumps are working, then the distributor will have to choose the two most important delivery pipes.



HRT Hospital with Damage

management engineering engineering management management engineering

	y(t)	$x_1(t)$	$x_2(t)$	$x_3(t)$	$x_4(t)$	$m_1(t)$
Operability	Patients per hour	Electricity (kW)	Water (L/h)	Doctors	Nurses	Physical Integrity
100%	20	100	1,000	4	8	100%
75%	15	50	500	3	6	80%
50%	10	30	300	2	4	50%
25%	7	20	200	2	3	20%
0%	0	0	0	0	0	0%

- Notice that the columns in an HRT must be monotonically increasing from bottom to top. For this reason, "Physical Integrity" is used instead of physical damage for the input damage modifier.
- Operability is determined by the least available resource. In the example water is the limiting factor.
- Since only 30 kW of electricity, etc. are needed, we can reallocate electricity, doctors, etc. to other hospitals or other cells, internal or external.

HRT Hospital with Tired Doctors

psychology

(*)	y(t)	$x_1(t)$	$x_2(t)$	$m_1(t)$	$m_2(t)$	(*)
Operability	Patients per hour	Doctors	Nurses	Physical Integrity	Doctors Shift Factor	Doctors Shift Hours
100%	20	4	8	100%	100%	10
75%	15	3	6	80%	75%	15
50%	10	2	4	50%	50%	20
25%	7	2	3	20%	25%	35
0%	0	0	0	0%	0%	> 48

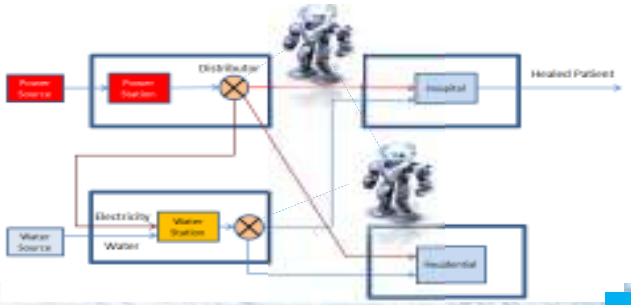
- In this example we suppose that electricity and water are not lacking, but doctors' shifts are very long. A modifier column can be added to account for this condition. The example assumes that the Nurses' shifts are optimum.

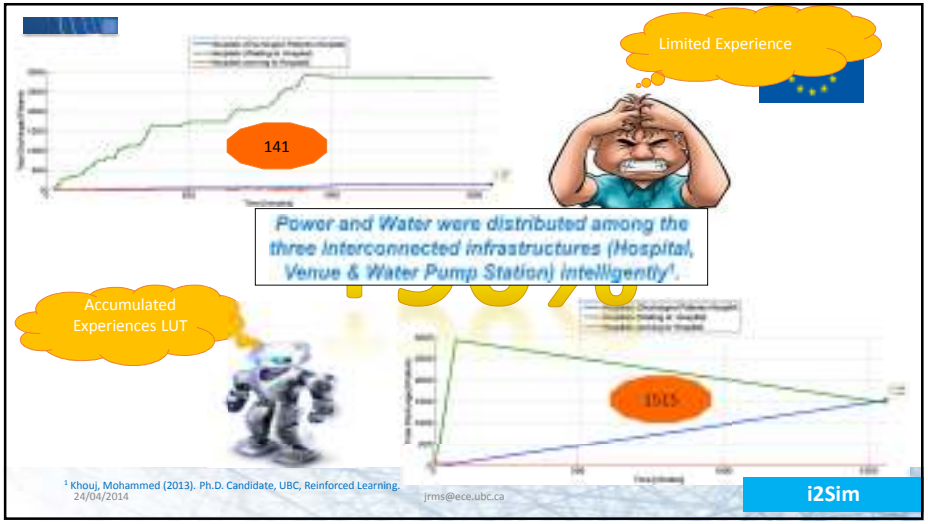
(*) Only the y(t), x(t), and m(t) columns are needed for the model. The other columns are descriptive comments.

RESPONSE OPTIMIZATION

Optimum Distributor Choices

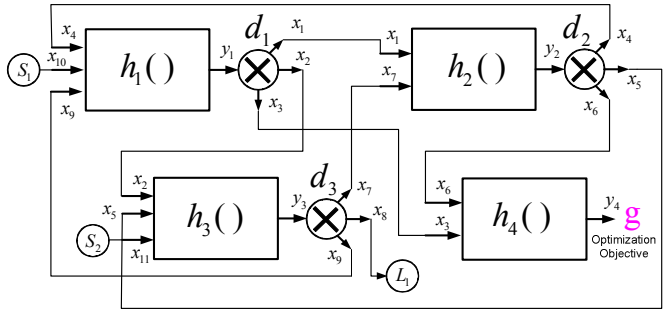
- The Distributor is controlled by an "intelligent agent" that will make the best decision in allocating the resources over the scenario time span (e.g., ten hours).
- Optimization of the allocation is made in terms of maximizing the system global objective. In the case of disasters, saving human lives.





[1] Khouj, Mohammed (2013). Ph.D. Candidate, UBC, Reinforced Learning.

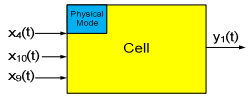
Mathematical Formulation



Synthesis of Cell Functions

q_1	q_2	q_3
y1	x4	x10	x9
16	8	5	15
12	7	4	10
8	5	2	7
4	2	1	3
0	0	0	0

$$q_1(x_4) = a_{04} + a_{14}x_4 + a_{14}x_4^2$$
$$q_2(x_{10}) = a_{010} + a_{110}x_{10} + a_{210}x_{10}^2$$
$$q_3(x_9) = a_{09} + a_{19}x_9 + a_{29}x_9^2$$



$$h_1(x_4, x_{10}, x_9) = \min\{q_1(x_4), q_2(x_{10}), q_3(x_9)\}, \text{ etc.}$$

The columns of the HRT form a set of linearly independent eigenvectors

Because of the linear independence of the q( ) functions, the Jacobians for the Newton and Lagrange solutions are very easy to evaluate.

The Jacobians for the Distributor functions equal the distributor ratios.

Cell and Distributor Equations

Cell Equations

$$h_1(x_4, s_1, x_9) = y_1$$
$$h_2(x_1, x_7) = y_2$$
$$h_3(x_2, x_5, s_2) = y_3$$
$$h_4(x_6, x_8) = g$$

Dummy Variables

$$y_1 = x_1 + x_2 + x_3$$
$$y_2 = x_4 + x_5 + x_6$$
$$y_3 = x_7 + x_8 + x_9$$

Distributor Equations

$$x_1 = k_1 y_1$$
$$x_2 = k_2 y_1$$
$$x_3 = (1 - k_1 - k_2) y_1$$
$$x_4 = k_4 y_2$$
$$x_5 = k_5 y_2$$
$$x_6 = (1 - k_4 - k_5) y_2$$
$$x_7 = k_7 y_3$$
$$x_8 = L_1$$
$$x_9 = (1 - k_7) y_3 - L_1$$

Newton-Raphson Iterations with Lagrange Optimization

g = Objective Function

Lagrange with Newton's Jacobians can be used to speed up optimum allocations.

- **GUADELOUPE Island**
- **Japan Disaster**
- **Smart Grid**

APPENDIX: SAMPLE SCENARIOS

- February 2010, City of Vancouver
- Strategic Support for Defence Research and Development Canada (DRDC)

VANCOUVER 2010 WINTER OLYMPICS

Critical Infrastructure[1]

[1] Juárez, Hugón (2012) Ph.D. Thesis, UBC, August.

Base Simulation

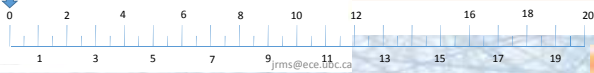
Event # 0, t=0 min — 05:11 PM

-Intensity VI Earthquake.
-MUR is out.
-DGR effective operability to Red due to MUR.
-BC Place, GM Place, VGH, SPH suffers slight physical damage and goes into (PM02).
-VGH, SPH, BC Place and GM Place effective operability to Red due to lack of water and electricity.
-VGH switches from MUR to SPG to receive electricity but it's only 50% functional.
-Electrical feeder from CSQ to GM Place is broken (PM05).
-Roads not damaged but 2*time delay because traffic lights are out (PM03).
-Water Station goes into (PM02) due to light physical damage, but effective operability to Red due to lack of electricity.
-A main water pipeline from Water Station to VGH is broken in Cambie Bridge due to shaking (PM05).

Results:

-BC Place: Estimated 120 casualties. (0.2% of total).
-GM Place: Estimated 38 casualties. (0.2% of total).
-BC Place, GM Place, SPH & VGH: 0% functional.
-Due to traffic, no injured patients to hospitals for 2 hours.

Minutes Timer



Timeline of Events (1)

Event # 1, t<1 min — 05:11 PM

-GM Place and BC Place emergency lights come on.
-GM Place and BC Place effective operability to orange but still needs electricity.

Results:

-People begin to evacuate from venues, evacuation time will take 2 hours.
- Backup generators for hospitals and water station kick in (power will be provided in 20 min.).

Event # 2, t=10 min — 05:21 PM

-Professionals call for repair crews.

Results:

-Authorities are notified of damage. Engineers will take 2 hours to arrive and start the structural assessment of bridges and critical assets.

Event # 3, t=20 min — 05:31 PM

-Water Station back-up generator comes on (effective operability to Yellow).
-VGH back-up Water pump and back-up generator come on (effective operability to Yellow).
-SPH back-up generator comes on (effective operability to Blue).

Results:

-Water Station: Water begins to flow again.
-VGH & SPH: With water and power, hospitals can begin treating patients.

Event # 4, t=1 hour — 06:11 PM

-Police arrive to clear up the traffic in the roads.
-Cambie Bridge water pipeline breakage is reported.

Results:

-Traffic problems start to be sorted out (effects not seen for another hour).
-Authorities can decide how to address water pipe damage (Repair crews will take another hour to arrive).

Timeline of Events (2)

Event # 5, t=2 hours — 07:11 PM

-Electrical feeder to GM place is fixed to 100% (PM01).
-Traffic starts clear up due to police.
-Repair crews are sent to fix the main water pipeline at Cambie Bridge.
-Engineers are sent to assess the structural conditions of VGH, SPH, BC Place, GM Place, and Water Station.

Results:

-Human Channel: Time delay from traffic reduces from 2x to 1.5x normal.
-GM Place effective operability to yellow.
-SPH & VGH: Patients start arriving.

Event # 6, t=5 hours — 10:11 PM

-Engineering Assessment is completed.
-Traffic goes back to normal.

Results:

-Repair and debris removal of buildings can begin.
-Human Channel: physical operability returns to 100%.

Event # 7, t=7 hours — 12:11 AM

-Water pump station repair is completed, (physical operability to PM01).

Results:

-Water Station: effective operability returns to Green, water supply returns to hospitals except VGH due to breakage of a main water pipeline at Cambie Bridge.

Event # 8, t=7.5 hours — 12:41 AM

-Water pipeline at Cambie Bridge has been repaired (physical operability to PM01).

Results:

-Water returns to VGH, backup water supply turned off.

Timeline of Events (3)

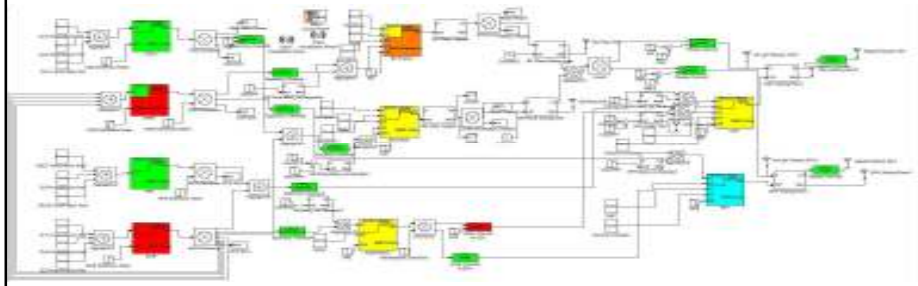
Event # 9, t=8 hours	01:11 AM
-GM Place has been repaired (physical operability to PM01).	
Results:	
-GM Place returns to 90% functionality, effective operability to Green.	

Event # 10, t=10 hours	03:11 AM
-SPH has been repaired (physical operability to PM01).	
Results:	
-SPH returns to 100% functionality (effective operability to Green). The number of waiting room patients stops increasing.	

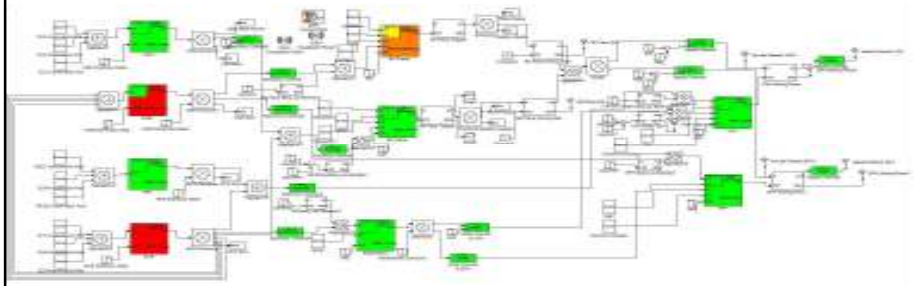
Event # 11, t=11 hours	04:11 AM
-VGH physical damage is repaired (physical operability to PM01).	
Results:	
-VGH returns to 100% functionality (effective operability to Green). The number of waiting room patients starts decreasing.	

Event # 12, t=12 hours	05:11 AM
-BC place 90% restored: physical operability to (PM01).	
Results:	
-BC Place effective operability still at Orange due to lack of electricity.	

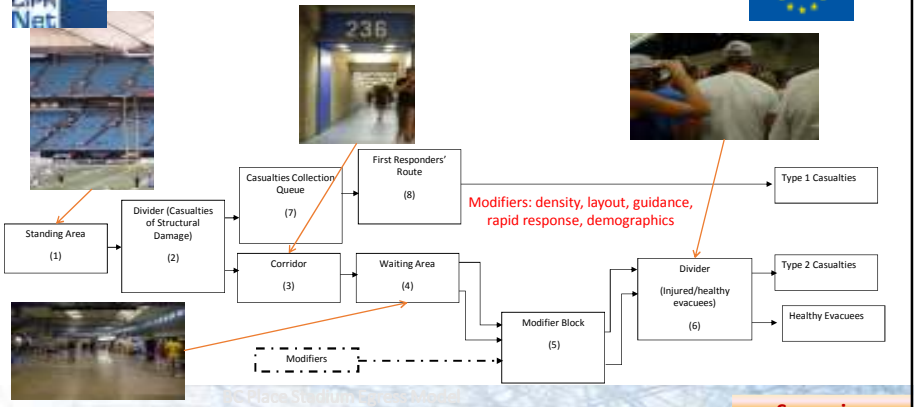
Event # 6, t=5 hours



Event # 11, t=11 hours



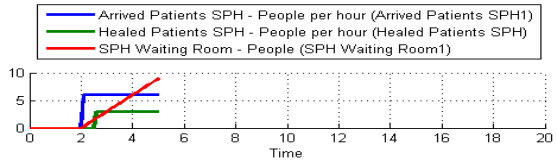
B.C. Place Egress Model[1]

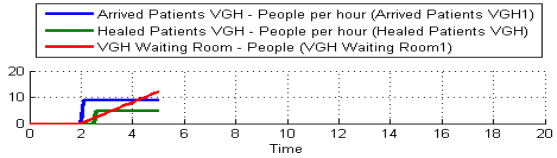


[1] Martí, Catherine (2009) Project Report, UBC, July.

65

Event # 6, t=5 hours (1)





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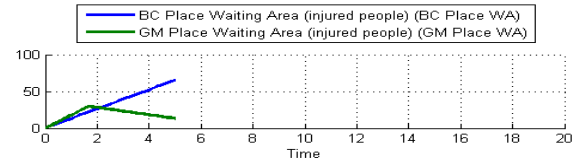
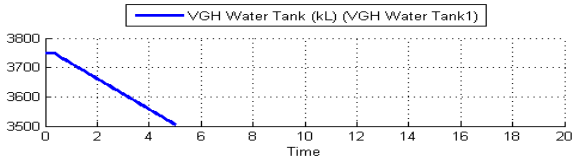
Event # 6, t=5 hours (2)





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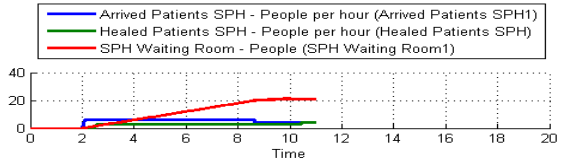
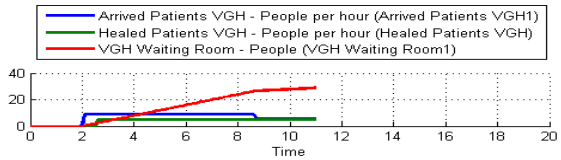
Event # 11, t=11 hours (1)





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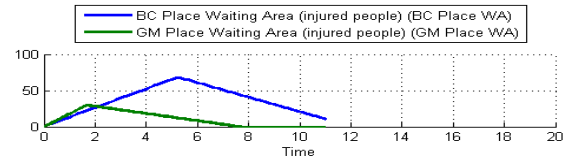
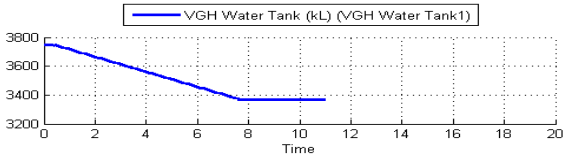
Event # 11, t=11 hours (2)





- MATRIX fp7 EU Project: Multi-Hazard and Multi-Risk Assessment Methods in Europe

GUADELOUPE ISLAND

The Guadeloupe Island Disaster Scenario[1]

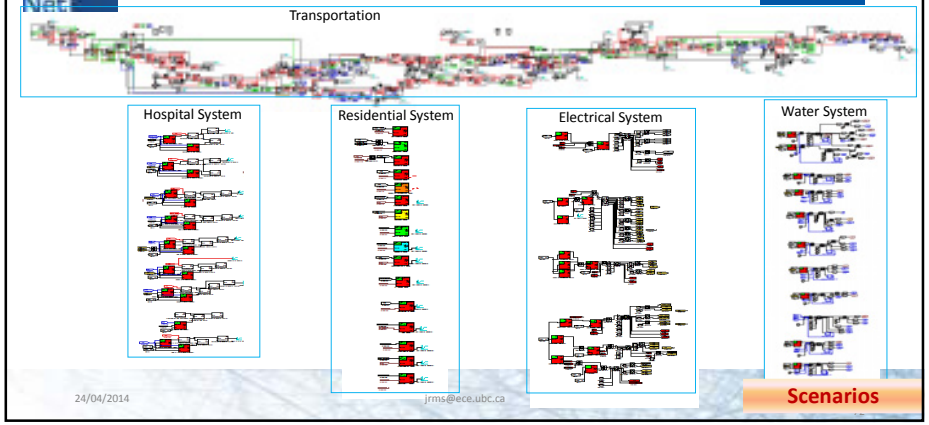
- Located in the French West Indies, in the composing of 5 groups of islands
- Approximately 402,000 inhabitants cover
- Grande-Terre and Basse-Terre are the tw

[1]Wang, Justin (2013) M.A.Sc. Thesis, UBC, January .

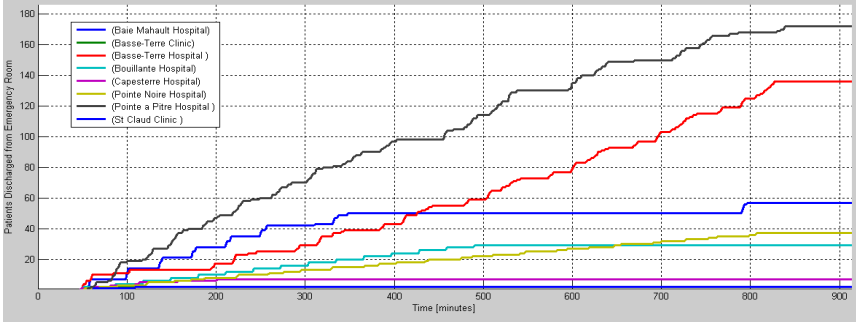
Modelled Infrastructure

- 59 Production Cells
  - Power Stations and Substations
  - Hospitals and Clinics (Each with Emergency Room and Ward)
  - Water Stations
  - Communities
- 349 Channel Cells
  - Bi-Directional Roads
  - Water Pipes
- More than 100 Distributors (Decision Points)
  - Power and Water Distribution
  - Intersections
  - Ambulance Dispatch
- Other miscellaneous Cells
  - Sources, Storage etc.

i2Sim Model



Patients Treated in Hospitals (Optimum Solution)



- March 2011, City of Sendai

JAPANS' DISASTER

Japan Sendai Disaster Timeline[1]

No	Time (min)	Event
1	0	Normal conditions (fact)
2	46	Earthquake M = 9.0 (fact)
3	53	A tsunami warning is issued for the coastal area of Japan (fact)
4	54	An evacuation process is going on (fact)
5	75	The first tsunami wave hits the impact zone (fact)
6	95	Water retreats (fact)
7	160	Survivors start evacuating the impact zones (assumption)
8	220	Road are prepared to begin the triage, search and rescue process (assumption)
9	221	The process for transportation of survivors and casualties begins (assumption)
10	300	Ambulance dispatch goes down
11	400	Ambulance dispatch restored
12	500	Medical supplies depleted at serious injury hospitals
13	600	Additional medical supplies provided to serious injury hospitals
14	800	Food decreases at shelter

[1]William (Tiange) Wang (2012) M.A.Sc. Thesis, UBC.

Reported Information

Situation of Affected Area in Miyagi Prefecture[3]

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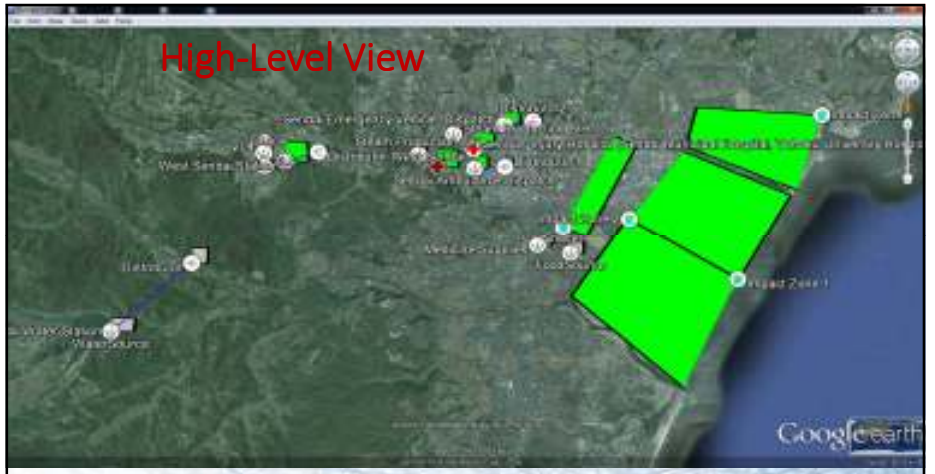
Disaster Zones

High-Level View



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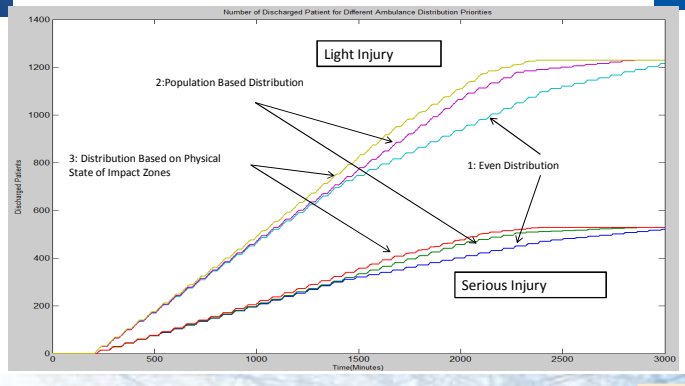
Response Strategies



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SMART GRID

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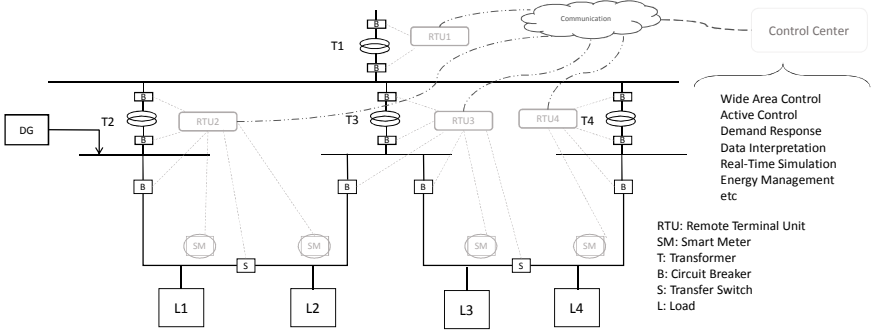
Power & Communication Systems



Wide Area Control
Active Control
Demand Response
Data Interpretation
Real-Time Simulation
Energy Management
etc

RTU: Remote Terminal Unit
SM: Smart Meter
T: Transformer
B: Circuit Breaker
S: Transfer Switch
L: Load

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Conclusions

- It is possible to model engineering systems and human systems in the same mathematical framework.
- It is possible to model interdependencies among critical infrastructures at the interdependency links while hiding the internal details of the CI.
- Very fast solution speeds can be achieved for large and complex systems by partitioning the solution.
- The i2Sim federated framework applies and extends the capabilities of MATE to allow for real time solutions of large multi-CI System of Systems including hybrid engineering/human systems.

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THANK YOU

Appendix C – List of Attendees

CIPRNet

Critical **I**nfrastructure **P**reparedness and **R**esilience Research **Net**work

CIPRNet Course inside the Master in Homeland Security ed. 1
Modelling, Simulation and Analysis of Critical Infrastructures

UCBM, Rome – 10th -11th July 2014

SURNAME	FIRST NAME
Angelucci	Nicola
Cristaldi	Danilo Francesco Maria
D'Agostino	Daniela
Donfrancesco	Ivan
Errico	Gabriella
Ferrari	Michela
Freni Sterrantino	Giovanni
Girella	Andrea
Giulisano	Anna Roberta
Ianniciello	Marco
Iossa	Antonio
Kallistova	Iunia
Maniscalco	Fabio
Nitti	Arturo
Palumbo	Carlo
Raimondo	Domenico
Ramundo	Alessandro
Raucci	Roberto
Valente	Andrea
Di Luzio	Marco

Appendix D – Certificate of Attendance

CIPRNet

Critical Infrastructure Preparedness and Resilience Research Network

CERTIFICATE OF ATTENDANCE

Name

Hereby recognised for participation in

Course on Modelling, Simulation and Analysis of Critical Infrastructures

Organised by University Campus Bio-Medico of Rome

July 10th - 11th, 2014
Rome (Italy)

Prof. Roberto Setola
(UCBM)

Dr. Erich Rome
(Fraunhofer)
Project Coordinator

Appendix E – Participant satisfaction feedback

CIPRNet

Critical **I**nfrastructure **P**reparedness and **R**esilience Research **Net**work

Course on Modelling, Simulation and Analysis of Critical Infrastructures

PARTICIPANT SATISFACTION FORM

Organised by University Campus Bio-Medico of Rome

July 10th – 11th, 2014
UCBM, Rome (Italy)

1 Instructions

The aim of this questionnaire is to collect information about the CIPRNet Course with respect to each teacher and lesson. Please spend some time filling in the questionnaire, as **your feedback is paramount for our improvement**.

For some of the questions in the following form, please indicate a score from 1 to 5 (1 = very bad, 5 = excellent). Moreover, there are some open-ended questions for you to provide comments; please fill in these fields with as much detail as possible (using further space if needed).

The Participants satisfaction form is filled out anonymously.

2 General Aspects

Question	*Score*
What is your overall opinion about this course?	
Is the time scheduling adequate?	
Did the course contents cover your expectations?	
Were the facilities adequate?	
Was it interesting/useful having English lessons?	
What were the most positive aspects of this course?	
Which aspects should be improved in terms of topics, clarity, and time scheduling?	
Notes (please provide general comments and suggestions)	

2.1 Day 1 – 10th July 2014

Introduction to CIPRNet by Erich Rome (Fraunhofer) [10:10 – 10:50]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

From critical infrastructure protection to critical infrastructure resilience by M.Theocharidou (JRC) [10:50 – 11:30]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Simulation of Critical Infrastructures (CI): relevant applications by Eric Luiijf (TNO) [11:30 – 12:10]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Principal modelling techniques: applications and limitations by Mohamed Eid (CEA) [12:30 – 13:10]

Question	*Score*
What is your overall opinion about this module?	

Notes (please provide general comments and suggestions regarding this module)

Modelling and investigating dependencies of CI by Roberto Setola (UCBM) [13:10 – 14:00]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Topological properties of complex networks and their relevance for CI by Vittorio Rosato (ENEA) [15:00 – 15:40]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Introduction to the Decision Support System (DSS) in the area of Risk management of CI by Vittorio Rosato (ENEA) [15:40 – 16:20]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Modelling and, Simulation and Analysis Techniques for CIP by Erich Rome (Fraunhofer) [16:40 – 17:20]

Question	*Score*

What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

OpenMI – Introduction, basic concepts and live demonstration by B. Becker and A. Zijderveld (Deltares) [17:20 – 18:30]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

2.2 Day 2 - 11th July 2014

Introduction to federated simulation by E. van Veldhoven (TNO) [9.00 – 9.40]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Verification and validation techniques by Edwin van Veldhoven (TNO) [9:40 – 10:20]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Geographical information systems for visualisation and analysis by Maurizio Pollino (ENEA) [10:20 – 11:00]

Question	*Score*

What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Events prediction and environmental sensing by Annette Zijderveld (Deltares) [11.20 – 12.00]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

Phenomenological approaches to simulate system of systems by A.Tofani (ENEA) [12:00 – 12:40]

Question	*Score*
What is your overall opinion about this module?	
Notes (please provide general comments and suggestions regarding this module)	

COMMENTS FROM PARTICIPANTS

(1) I think that in the first lecture or, better, in the Introductory lecture, a overall plane of the MasterClass must be given. It should be made clear which is the objective of the MasterClass and which is the "pedagogical" flow that we have in mind. In this way the "student" can better frame the contents of a particular lecture within the information scheme followed in the MasterClass. Having in mind this scheme, and having as one of the first slides of each presentation the "location" in the flow, the student will be facilitated to follow the contents and to frame those information in a picture.
A possible flow could be
- CIP: what it is and what scenarios should be able to tackle
- What CIPRNET intends to realize (in terms of objectives and technol results)
- Which are the main (hard) problems to tackle?
    - dependencies and interdependencies
    - lack of informations etc
- Whose are the main technologies that the consortium will deploy/develop to reach its goals?
    - Geomatic
    - Topological and abstract models
    - Hydrologic and hydraulic models
    - Federated models and domain simulators
    - Macroscopic and phenomenological models (I2Sim)
    -Techniques for validating models
- Which are the current state of the CIPRNET outcomes
    - The DSS
    - CIPedia
    - What if tool
    - Outages repository (I would also add this issue..)

(2) Some lectures are too qualitative. Might be in the Masterclass at UCBM was not a real issue as many of the students had non technical background. However, with more technological audience I think that we should venture to say more on the technical/scientific sides.

(3) After the last presentation of the CIPRNet course last Friday in Rome, we had a short discussion with the students over the course. This were the most important points:

- They were positive about now understanding more the EU approach for CI research and tools, this was something they had hoped for.
- They found the course interesting and helpful for their future work
- There could be more accent on the human factor in the decision making and DSS support, now it was very much only on technology
- Validation of models/ DSS should be done on real past cases, it is much more powerful than theoretical examples

I personally would have liked to have some more audience, maybe we should think to open the summer course also to other students.